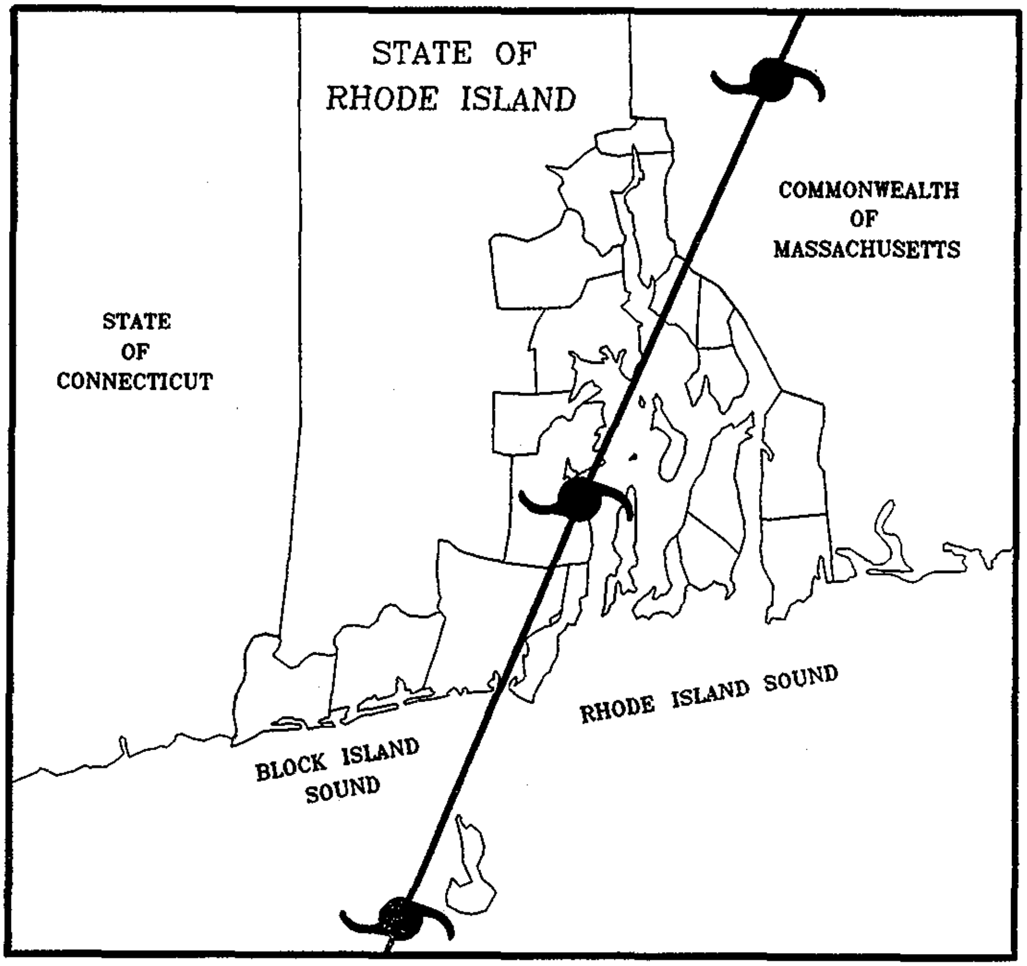
May 1995

Rhode Island Hurricane Evacuation Study
Appendices A, B, and C



US Army Corps of Engineers
New England Division

FEDERAL EMERGENCY MANAGEMENT AGENCY

APPENDIX A

Storm Surge Atlas for the Narragansett Bay, Rhode Island and Buzzards Bay, Massachusetts Area

A STORM SURGE ATLAS FOR THE NARRAGANSETT BAY, RHODE ISLAND AND BUZZARDS BAY, MASSACHUSETTS AREA

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1. INTRODUCTION

Storm surge is the abnormal rise in water level caused by wind and pressure forces of a hurricane. Storm surge produces most of the flood damage and drownings associated with tropical storms that make landfall or that closely approach a coastline (Anthes, 1982).

A numerical storm surge model developed by Jelesnianski (1967, 1972), Jelesnianski and Taylor (1973) and Jelesnianski et al. (1984) has been applied to the Narragansett Bay, RI and Buzzards Bay, MA region. The model, which calculates sea, lake and overland surges from hurricanes, and has the acronym "SLOSH," is a pairing of a model of a hurricane coupled to a model for storm surge. Crawford (1979) discussed some preliminary results using this model in the southeast Louisiana region.

The purpose of this atlas is to provide maps of SLOSH-modeled heights of storm surge and extent of flood inundation, for various combinations of hurricane strength, forward speed of storm and direction of storm motion. Strength is modeled by use of the central pressure and storm eye size using four of the five categories of storm intensity (Table 1), developed by Saffir and Simpson (Simpson and Riehl, 1981). Six storm-track headings were selected as being representative of storm behavior in this region on the basis of observations by forecasters at NOAA's National Hurricane Center.

The maps in this atlas summarize surge calculations made using the SLOSH model, when initialized with observed values (depths of water and heights of terrain and barriers) in the region centered on Narragansett Bay, RI and Buzzards Bay, MA.

2. THE GRID FOR THE SLOSH MODEL OF THE NARRAGANSETT AND BUZZARDS BAYS AREAS

Figure 1 illustrates the area covered by the grid for the Narragansett and Buzzards Bays SLOSH model. The area covered by the grid is called a

Table 1. Saffir/Simpson hurricane intensity categories.

	Central Pressure		Wind Speed		
Category	Millibars	Inches (Hg)	Miles per Hr.	Knots	Damage
1	≥ 980	≥ 28.9	74 - 95	64 - 83	Minimal
2	965 - 979	28.5 - 28.9	96 - 110	84 - 96	Moderate
3	945 - 964	27.9 - 28.5	111 - 130	97 - 113	Extensive
4	920 - 944	27.2 - 27.9	131 - 155	114 - 135	Extreme
5	< 920	< 27.2	> 155	> 135	Catastrophic

"basin"--the "Narragansett and Buzzards Bays Basin." The grid is a telescoping polar coordinate system with 80 arc lengths ($1 \leq I \leq 80$) and 82 radials ($1 \leq J \leq 82$). Unlike a true polar coordinate grid, which would have radial increment (ΔR) that was invariant with radius, this grid uses a ΔR that increases with increasing distance from the grid's pole. The result is that in each grid of the mesh, the increment of arc length (ΔS) of the side of a grid "square" is approximately equal to the radial increment of the "square," or $\Delta S \approx \Delta R$.

The telescoping grid is a compromise between conflicting needs. What is desired is that the model domain include a large geographical area, but also that small, detailed topography be included in the model. In a Cartesian coordinate system, this combination of big area, but spatially-small grid increment, requires that a computational mesh with many grid squares be used. A large mesh requires a computer with a large central processing unit (CPU) as well as more time to perform calculations in the more numerous grid squares. The telescoping grid, by comparison, permits a resolution of these conflicting needs: it has an acceptably small spatial resolution of 1 to 10 mi^2 per grid square over land, which is the area of greatest interest. Thus, topographic details, such as highway and railroad embankments, and dikes in harbors of cities are included in the model. However, the range increment contained in each grid square becomes progressively larger with increasing distance from the pole. As a result, a large geographic area is included in the model, so that the effects of the model's boundaries on the dynamics of the storm are diminished and the storm's physics are better emulated.

The grid is tangent to the earth at the basin center, Quicksand Point on the Rhode Island-Massachusetts border at 41°27'N and 71°24'W. There, the grid increment is 1.25 statute miles. The pole (or origin) of the grid is located at 42°N and 71°01'W.

The telescoping grid has some disadvantages. Primarily, these stem from the distortion that occurs when the basin is remapped onto a display that has constant-sized increments in the vertical and horizontal, as happens when the basin is printed out by a conventional (computer) line printer. This distortion from remapping produces some difficulties in "reading" the results by the uninitiated. For example, neither latitude nor longitude lines remain uncurved and "parallels" become non-parallel. However, the projection is conformal. The projection scheme results in each grid square at I = 1, closest to the pole, representing an area of about 0.35 square mile. By contrast, at maximum distance from the pole, at I = 80, each grid square contains about 33.5 square miles. Thus, the distortions require that aids be provided to "read" and interpret the results.

3. SLOSH MODEL

A. Hurricane Model and Input

The hurricane model which drives the storm surge model was developed by Jelesnianski and Taylor (1973). It is a trajectory model of a stationary vortex and it balances the forces from pressure gradient, centrifugal, Coriolis and surface frictional effects. Adjustments are made to the computed vector wind to incorporate the hurricane's forward motion. The model's input includes the radius of maximum wind (RMW) and the difference (ΔP) in sea-level pressure between the ambient value and the minimum value in the storm's center. Directly measured wind vectors are not used. The model also requires input of the coordinates of the storm's center. Thus, input data include thirteen sets of latitude, longitude, ΔP and RMW, at six hour increments, beginning 48 hours before storm landfall and ending 24 hours after landfall. These 13 sets are then linearly interpolated into values/positions at hourly (or smaller) time increments. The model then generates the meteorological forces--surface stress and the gradient of atmospheric pressure-that drive the underlying ocean.

B. Storm Surge Model

Storm surge is the response by the ocean to meteorological forces. The model's governing equations are those given by Jelesnianski (1967), except now for the inclusion of the finite amplitude effect. Coefficients for surface drag, eddy viscosity and bottom slip are the same as those used in an earlier model (Jelesnianski, 1972). There is no calibration or tuning to force agreement between observed and computed surges; coefficients are fixed, and do not vary from one geographical region to another.

Special techniques are incorporated to model two-dimensional inland inundation, routing of surges inland when barriers are overtopped, the effect of trees, the movement of the surge up rivers, and flow through channels, cuts and over submerged sills. Besides surge, other processes affect water height (section 4B), but are not incorporated in the model.

Not surprisingly, the accuracy of modeled surge values increases as the accuracy of the input terrain and storm data improves.

4. OUTPUT AND INTERPRETATION OF THE MODEL RESULTS

A. Output from the SLOSH Model

The output for the Narragansett and Buzzards Bays "SLOSH" model consists of maps of water heights. At each grid point, the water height is the maximum value that was computed at that point during the 72 (maximum) hours of model time. Thus, the map displays the highest water levels and does not display events at any particular instant in time. The analyzed envelopes of high water show shaded areas that represent dry land which has been inundated and contours of high water relative to mean sea level (MSL). Height of water above terrain was not calculated because terrain height varies within a grid square. For example, the altitude of a grid square may be assigned a value of 6-ft MSL, but this value represents an average of land heights that may include values ranging from 3 ft to 9 ft MSL. Thus, a surge value of 8 ft in this square, implying 2 ft average depth of water over the grid's terrain, would include some terrain without inundation and other parts with as much as 5 ft of overlying water. Therefore, the depth of surge flooding above terrain at a specific site in the grid square is deduced by subtracting the actual terrain height from the model-generated storm surge height in that square. Also supplied are printout lists of values of surge height, wind speed and wind direction for each of 80 sites. The values are ten-minute averages, every 30 minutes. These are useful for determining the time of onset of gale force winds and surge heights, for evacuation planning.

B. <u>Interpretation of Results</u>

Even if the model is supplied accurate data on storm positions, intensities and sizes, the computed surges may contain errors of +/- 20% of observed water levels. These primarily stem from:

1) Maps that are outdated: The maps which supplied heights of terrain and depths of water sometimes did not include changes, often man-made, that had been made to the heights and positions of barriers (e.g., highway and railway embankments) and depths and locations of channels. Inaccuracies of topography or bathymetry will contribute directly to errors in the modeling of all storm surges.

2) Anomalous water heights: Sea level can be at an altitude different from "mean sea level," days or even weeks before a storm is actually affecting a basin. The value of the actual, local sea level -- the "local datums" for pre-storm anomaly in the Atlantic Ocean -- must be supplied to the model, before calculations are initiated.

3) Local processes, such as waves, astronomical tides, rainfall and flooding from overflowing rivers: These processes are usually included in "observations" of storm surge height, but are not surge and are not calculated by the SLOSH model.

Factors such as the foregoing must be considered when comparisons are made between modeled and observed values of storm surge.

5. HURRICANE CLIMATOLOGY

A. Tracks

Between 1886 and 1987, 21 tropical cyclones of hurricane intensity passed within 105 statute miles of Quicksand Point, RI/MA (Neumann et al., 1985), for an average of one hurricane within the 105-mile circle every 4.8 years (see Table 2).

Figures 2-4 show the tracks of these 21 storms with hurricane force winds. Figure 2 depicts the tracks for northwestbound and northbound storms, Figure 3 shows tracks for storms heading north-northeastward, and Figure 4 displays the tracks of storms heading northeastward or east-northeastward. In Figures 2-4, the tracks are labeled at 6-h intervals with month/day/hour (GMT).

The tracks represent "best estimates" and are based on a variety of data sources. Historically, storm strength, location and motion were only inferred, from analyses of wind, pressure and cloud observations made at ships and land stations being influenced by the storm. In 1943, aircraft reconnaissance of hurricanes began. Not until 1959 were there land-based weather radars, as now at Atlantic City, New York City and Chatham, Massachusetts which could be used to observe and record structure, development and motion of precipitation fields, and help infer center location and radius of maximum winds. The 1960's saw the advent of photography of tropical storms from weather satellites. Observations by aircraft, radar and satellite have shown

Table 2. Hurricanes passing within 105 statute mile circle of Quicksand Point, RI/MA (41.45°N, 71.4°W), during 1886-1987.

>>> At Closest Point of Approach: (@CPA) <<<								
Index (1)	Date (@CPA) (2)	Storm Name (3)	Range/Bearing (miles/degrees) (to CPA) (4)	/ (5)	Wind (in circle) (mph) (6)	Storm Motion (@CPA) (dir / mph) (7)	/ (8)
1	1888 Nov 27	Unnamed	91	120	98	NNE	11
2	1891 Oct 14	Unnamed	77	132	98	NE	15
3	1896 Sep 20	Unnamed	89	087	108	N	10
4	1904 Sep 15	Unnamed	1	036	75	NE	53
5	1916 Jul 21	Unnamed	20	124	91	NNE	18
6	1924 Aug 26	Unnamed	73	112	106	NE	43
7	1927 Aug 24	Unnamed	75	130	105	NE	48
8	1933 Sep 17	Unnamed	99	136	81	NE	29
9	1936 Sep 19	Unnamed	40	140	92	ENE	32
10	1938 Sep 21	Unnamed	102	259	90	N	51
11	1940 Sep 2	Unnamed	98	123	81	NE	26
12	1944 Sep 15	Unnamed	40	296	83	NE	29
13	1953 Aug 15	Barbara	84	154	86	ENE	23
14	1954 Aug 31	Carol	64	279	96	NNE	35
15	1954 Sep 11	Edna	26	143	96	NNE	46
16	1958 Aug 29	Daisy	98	144	119	NE	28
17	1960 Sep 12	Donna	54	274	98	NNE	39
18	1961 Sep 21	Esther	46	160	127	NE	6
19	1962 Aug 29	Alma	90	127	98	NE	13
20	1969 Sep 9	Gerda	105	122	124	NNE	48
21	1985 Sep 27	Gloria	92	288	86	NNE	45

Notes:

(1) Storm number for this list.

(2) Year, month and date that storm had maximum winds exceeding 74 mph and was closest to Quicksand Point, RI/MA.

(3) Storms were not formally named before 1950.

(4)-(5) Distance (statute miles) and direction (degrees) from Quicksand Point to storm when it passed abeam.

(6) Maximum sustained wind speed near storm center while center was within 105 statute miles of Quicksand Point. This is not necessarily the wind recorded at a given site.

(7)-(8) Storm heading and forward speed (mph) at hour of closest point of approach.

that the tracks of centers of hurricanes contain wobbles, gyrations and cycloidal motions (Lawrence and Mayfield, 1977) and that there often are rapid developments in size and intensity of rain bands, contractions of eyewall diameters and formation of concentric ("double") eyewalls. These factors, poorly documented even today, indicate asymmetries in the storm's dynamical structure and can affect the storm's surge. But they usually are smoothed out of analyses, as in Figures 2-4.

B. Intensities

Hurricane intensity is usually defined by measurements at sea level of the maximum sustained wind speed and/or by minimum barometric pressure. Neither of these is easily obtained. Accurate estimates of these parameters at sea level were acquired only when a ship or land station was traversed by the storm's "eye." Minimum central pressure was gotten only when a barometer was in the precise path of the storm's center. Because the area covered by the strongest winds is much larger than that covered by the pressure minimum, strength of many older storms was deduced from measurements of wind speed. However, with the advent of aircraft reconnaissance, measurements made at flight level of meteorological parameters allow the calculation of barometric pressure at sea level. By comparison, winds at sea level are not so readily deduced from flight level data. For all the storm tracks in Figures 2-4, an estimate was made of the maximum wind speed at intervals of 6 hours. For some, only very indirect evidence exists of actual speeds. From the hourly values of the maximum wind speed inside the 105 mile circle, the largest value was selected. This maximum sustained wind speed for the hurricane is listed in Table 2 under the heading of "wind (in circle)." Storm heading and forward speed at hour of closest point of approach are listed in the last two columns.

The values listed in column 6 sometimes are poor estimates of the maximum wind speed; the following must be considered:

1) Actual wind speeds and directions exhibit gustiness.
2) The "average wind speed" has been calculated with a variety of time intervals over the years; thus, one can find historical wind records that have used time periods such as 1 hour, or 10 or 5 minutes or 1 minute as the "standard" period of measurement. Given the same record from a recording anemometer, the use of each of these measurement periods would likely yield a different average wind speed, with shorter periods probably giving higher average speeds.
3) The platforms for measuring maximum surface wind speed have changed over the years; data from ship and land stations now are supplemented by remotely-sensed data from aircraft, satellites and radar. However, the remote platforms, especially the last two, observe the motions of clouds or precipitation echoes, and these motions are not wind speed, nor are they at sea level.

Because of these limitations in determination of maximum wind speed, the SLOSH model uses storm-center sea-level pressure as a measure of storm intensity in modeling the Narragansett and Buzzards Bays basin.

6. MAPS OF MAXIMUM ENVELOPE OF WATER ("MEOW") FROM SLOSH RUNS USING DATA FOR HYPOTHETICAL HURRICANES

A. Hypothetical Storm Tracks and Populations

The skill of the SLOSH model was evaluated by Jarvinen and Lawrence (1985), who compared modeled and observed surges at 523 sites during 10 hurricanes. They found that the mean absolute error in surge height calculated by SLOSH was 1.4 ft. Although the error range was from -7.1 ft to

+8.8 ft, the standard deviation was only 2.0 ft and 79% of the errors lay within one standard deviation of the mean error, -0.3 ft. (On the average, modeled values were slightly less than those observed.)

Because of this skill in calculating storm surge, the SLOSH model was used to create maps of surge flooding in the Narragansett and Buzzards Bays basin for use in evacuation planning. The model was supplied with data from hypothetical storms and the resulting surge calculations were composited to produce maps of the maximum envelope of water. This section details why these calculations were made and how the compositing was done.

Storm surge height partly depends on distance between the location of a particular site and the storm's center. For a single storm, the model would produce a map of surge height for the modeled period of time (usually 72 hours), with values valid for only that particular storm track. If there were two storms, identical in every respect except that one followed a track parallel to, but separated from the other by 50 miles,[1] and if the model was run with first one and then the other set of storm parameters, and a comparison made of surge values, then very likely there would be geographical sites with surge values from one storm that differed markedly from those modeled for the other storm. This dependency of surge height on storm track can be troublesome, when preparing plans for emergency evacuation. Maps are needed for basin-wide surge flooding potential—maps showing surge height for only one intensity (using the categories defined by Saffir and Simpson), one

[1]A difference ("error") of 50 miles in storm track is not very large when compared to the vagaries of tracks of real hurricanes. The average error of 12-hour forecast landfall position, for U.S. Atlantic coast tropical cyclones, during 1970-1979, was about 59 statute miles, while for 24-hour forecasts, landfall position error was about 125 statute miles (Neumann and Pelissier, 1981). Thus, if a storm were forecast to make (eye) landfall at Quicksand Point, in 24 hours, and if, in fact, it made landfall <u>anywhere</u> between Rockaway Beach, Long Island and Rye Beach, New Hampshire, the error in forecast landfall position would be no worse than average.

storm speed and direction. We created such maps for this basin by making surge calculations for each of an ensemble of 3 to 12 storms all having the same intensity and speed and on parallel headings, separated by 15 miles. Then, at each grid square, the maximum surge value that was calculated from any storm in the ensemble was extracted and saved. After this procedure was performed for all grid squares, the result was a basin map depicting the "maximum envelope of water," or MEOW, for the specified storm category, direction and speed. For the Narragansett and Buzzards Bays basin, the hypothetical storms were specified to move in one of six directions, at one of three constant speeds, as summarized in Table 3. There were 8 tracks for the west-northwestward (WNW) moving storms (Figure 5), 10 tracks for the northwest-bound (NW) storms (Figure 6), 12 tracks for the north-northwest (NNW) storm headings (Figure 7), 12 tracks for the northward (N) moving storms (Figure 8), 11 tracks for the north-northeastward (NNE) storm headings (Figure 9), and up to 7 tracks for storms heading northeastward (NE), in Figure 10. In total, 536 hypothetical storms were run, using the SLOSH model, to create the results to be presented below. The selection of directions and speeds was based on advice of hurricane specialists at NOAA's National Hurricane Center.

B. Intensities and Radii of Maximum Winds of Hypothetical Storms

Most hurricanes weaken after making landfall because the central pressure increases (the storm "fills") and the RMW tends to increase. Table 4 summarizes pressure filling and RMW increases with time for the hypothetical storm runs. These rates of change were based partly on the work of Schwerdt et al. (1979). Storms heading northeastward were modeled to not undergo filling or to change RMW.

Table 3. Narragansett/Buzzards Bays Basin's hypothetical storms: Directions, speeds, (Saffir/Simpson) intensities, number of tracks and the number of runs.

Direction	Speed (mph)	Intensities	Tracks	Runs
WNW	20	1 through 4	8	32
NW	20	1 through 4	10	40
NNW	20, 40, 60	1 through 4	12	144
N	20, 40, 60	1 through 4	12	144
NNE	20, 40, 60	1 through 4	11	132
NE*	20, 40	1, 2, 3, 4	7, 7, 5, 3	44
				Total = 536

*Several NE moving hurricanes near or over land cannot maintain all intensity levels.

Table 4. Time change of pressure difference and radius of maximum wind for hypothetical hurricanes having headings towards the west-northwest, northwest, north-northwest, north or north-northeast in Narragansett and Buzzards Bays Basin.

Values of pressure difference (ΔP, millibars) and radius of maximum wind (RMW, statute miles), beginning at time of landfall (LF) of center of storm and every six hours after LF.

Category	Landfall		LF + 6		LF + 12		LF + 18		LF + 24	
	ΔP	RMW	ΔP	RMW	ΔP	RMW	ΔP	RMW	ΔP	RMW
1	20	30	14	30	10	30	10	35	10	40
2	40	30	31	30	22	30	13	35	10	40
3	60	30	48	30	36	30	24	35	12	40
4	80	30	65	30	50	30	35	35	20	40

C. Initial Water Height

Based on observations from tide gages in the area of this basin, tidal anomalies of about +1 ft MSL before arrival of a hurricane are not uncommon. Thus, all SLOSH runs of hypothetical hurricanes were supplied with initial datums of +1 ft MSL. In an actual hurricane, if tide gage data in this basin indicate that there is no tide anomaly, then subtract 1 ft from the modeled values found in the maps (below).

D. The "MEOW" Figures

There are 52 MEOWS and they use the distorted geography mentioned in Section 2. They are presented in the Appendix. The MEOW figures are grouped by direction: MEOWS for west-northwestbound storms are in Figures A1-A4, northwestbound storms' MEOWS are in Figures A5-A8, MEOWS for north-northwestbound storms are in Figures A9-A20, northbound storms' MEOWS are in Figures A21-A32, north-northeastbound storms' MEOWS are in Figures A33-A44, and northeast-moving storms' MEOWS are in Figures A45-A52. In the figures, the contours represent the height of water above mean sea level, in 1-ft increments, while the shaded areas indicate land areas that were modeled to have been inundated.

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8. APPENDIX: MAXIMUM ENVELOPES OF WATER (MEOW) SERIES "A"

Figure	MEOW
A- 1	West-northwestbound, 20 mph, category 1 hurricane.
A- 2	West-northwestbound, 20 mph, category 2 hurricane.
A- 3	West-northwestbound, 20 mph, category 3 hurricane.
A- 4	West-northwestbound, 20 mph, category 4 hurricane.
A- 5	Northwestbound, 20 mph, category 1 hurricane.
A- 6	Northwestbound, 20 mph, category 2 hurricane.
A- 7	Northwestbound, 20 mph, category 3 hurricane.
A- 8	Northwestbound, 20 mph, category 4 hurricane.
A- 9	North-northwestbound, 20 mph, category 1 hurricane.
A-10	North-northwestbound, 20 mph, category 2 hurricane.
A-11	North-northwestbound, 20 mph, category 3 hurricane.
A-12	North-northwestbound, 20 mph, category 4 hurricane.
A-13	North-northwestbound, 40 mph, category 1 hurricane.
A-14	North-northwestbound, 40 mph, category 2 hurricane.
A-15	North-northwestbound, 40 mph, category 3 hurricane.
A-16	North-northwestbound, 40 mph, category 4 hurricane.
A-17	North-northwestbound, 60 mph, category 1 hurricane.
A-18	North-northwestbound, 60 mph, category 2 hurricane.
A-19	North-northwestbound, 60 mph, category 3 hurricane.
A-20	North-northwestbound, 60 mph, category 4 hurricane.
A-21	Northbound, 20 mph, category 1 hurricane.
A-22	Northbound, 20 mph, category 2 hurricane.
A-23	Northbound, 20 mph, category 3 hurricane.
A-24	Northbound, 20 mph, category 4 hurricane.

A-25 Northbound, 40 mph, category 1 hurricane.

A-26 Northbound, 40 mph, category 2 hurricane.

A-27 Northbound, 40 mph, category 3 hurricane.

A-28 Northbound, 40 mph, category 4 hurricane.

A-29 Northbound, 60 mph, category 1 hurricane.

A-30 Northbound, 60 mph, category 2 hurricane.

A-31 Northbound, 60 mph, category 3 hurricane.

A-32 Northbound, 60 mph, category 4 hurricane.

A-33 North-northeastbound, 20 mph, category 1 hurricane.

A-34 North-northeastbound, 20 mph, category 2 hurricane.

A-35 North-northeastbound, 20 mph, category 3 hurricane.

A-36 North-northeastbound, 20 mph, category 4 hurricane.

A-37 North-northeastbound, 40 mph, category 1 hurricane.

A-38 North-northeastbound, 40 mph, category 2 hurricane.

A-39 North-northeastbound, 40 mph, category 3 hurricane.

A-40 North-northeastbound, 40 mph, category 4 hurricane.

A-41 North-northeastbound, 60 mph, category 1 hurricane.

A-42 North-northeastbound, 60 mph, category 2 hurricane.

A-43 North-northeastbound, 60 mph, category 3 hurricane.

A-44 North-northeastbound, 60 mph, category 4 hurricane.

A-45 Northeastbound, 20 mph, category 1 hurricane.

A-46 Northeastbound, 20 mph, category 2 hurricane.

A-47 Northeastbound, 20 mph, category 3 hurricane.

A-48 Northeastbound, 20 mph, category 4 hurricane.

A-49 Northeastbound, 40 mph, category 1 hurricane.

A-50 Northeastbound, 40 mph, category 2 hurricane.

A-51 Northeastbound, 40 mph, category 3 hurricane.

A-52 Northeastbound, 40 mph, category 4 hurricane.

9. FIGURE CAPTIONS

Figure 1. Grid mesh for SLOSH model for Narragansett/Buzzards Bays basin.

Figure 2. Tracks of hurricanes (1886-1986) passing within 105 miles of Quicksand Point, Rhode Island/Massachusetts: northbound storms only.

Figure 3. Same as Figure 2, but only storms heading north-northeastward.

Figure 4. Same as Figure 2, but only northeastward and east-northeastward moving storms.

Figure 5. Tracks of the hypothetical hurricanes that were used for calculating the maximum envelope of water (MEOW). Hurricane symbol is at point of landfall of eye of storm, and dots are eye positions at 6 hour increments (20 mph). Tracks are identified by the distance in miles of their landfall point to the left side (LS) or right side (RS) of Quicksand Point, Rhode Island/Massachusetts. Storms heading west-northwestward (WNW) only.

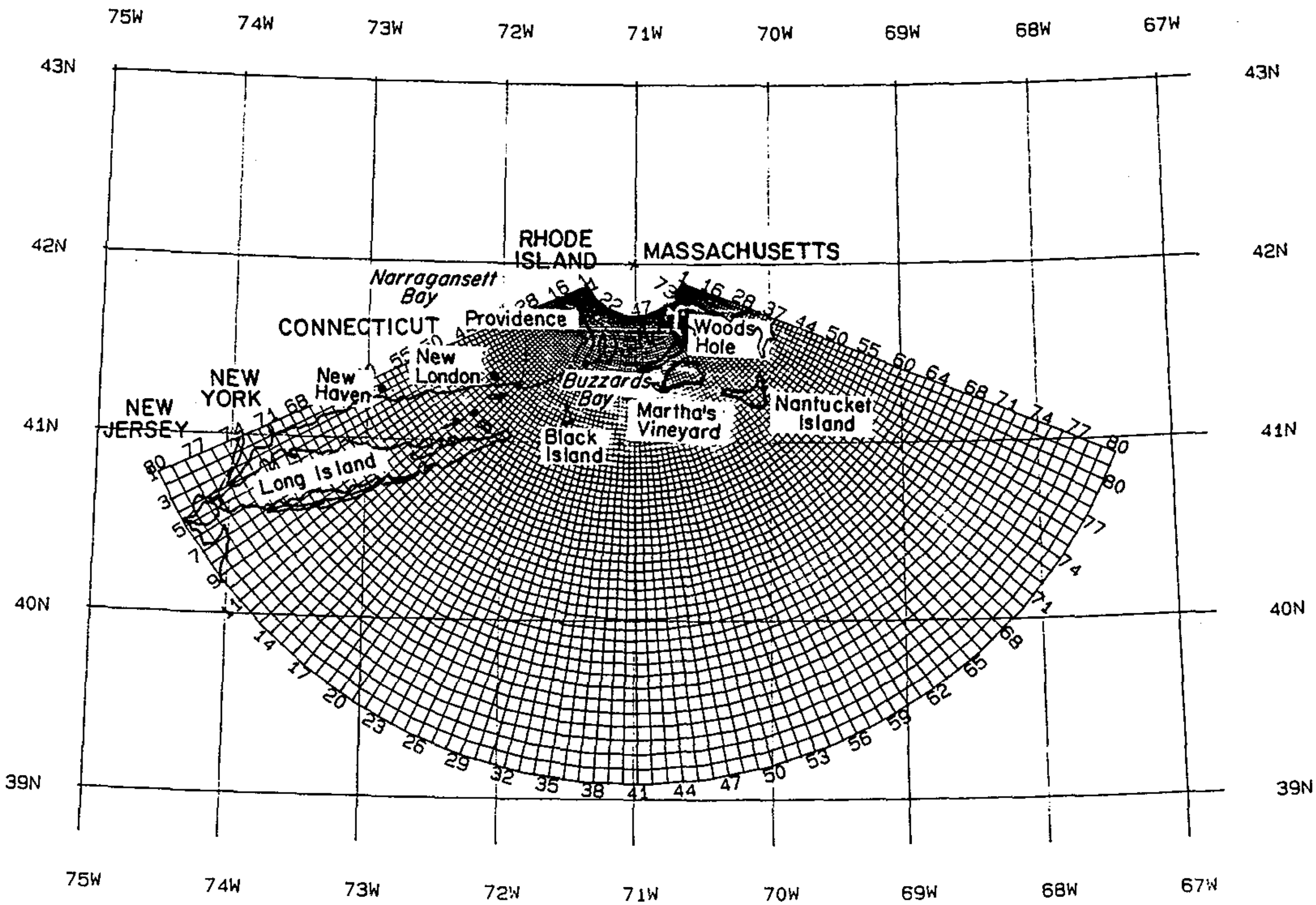
Figure 6. Same as Figure 5, but only for northwestbound (NW) storms.

Figure 7. Same as Figure 5, but only for north-northwestbound (NNW) storms.

Figure 8. Same as Figure 5, except for northbound (N) storms only.

Figure 9. Same as Figure 5, except for north-northeastward (NNE) moving storms only.

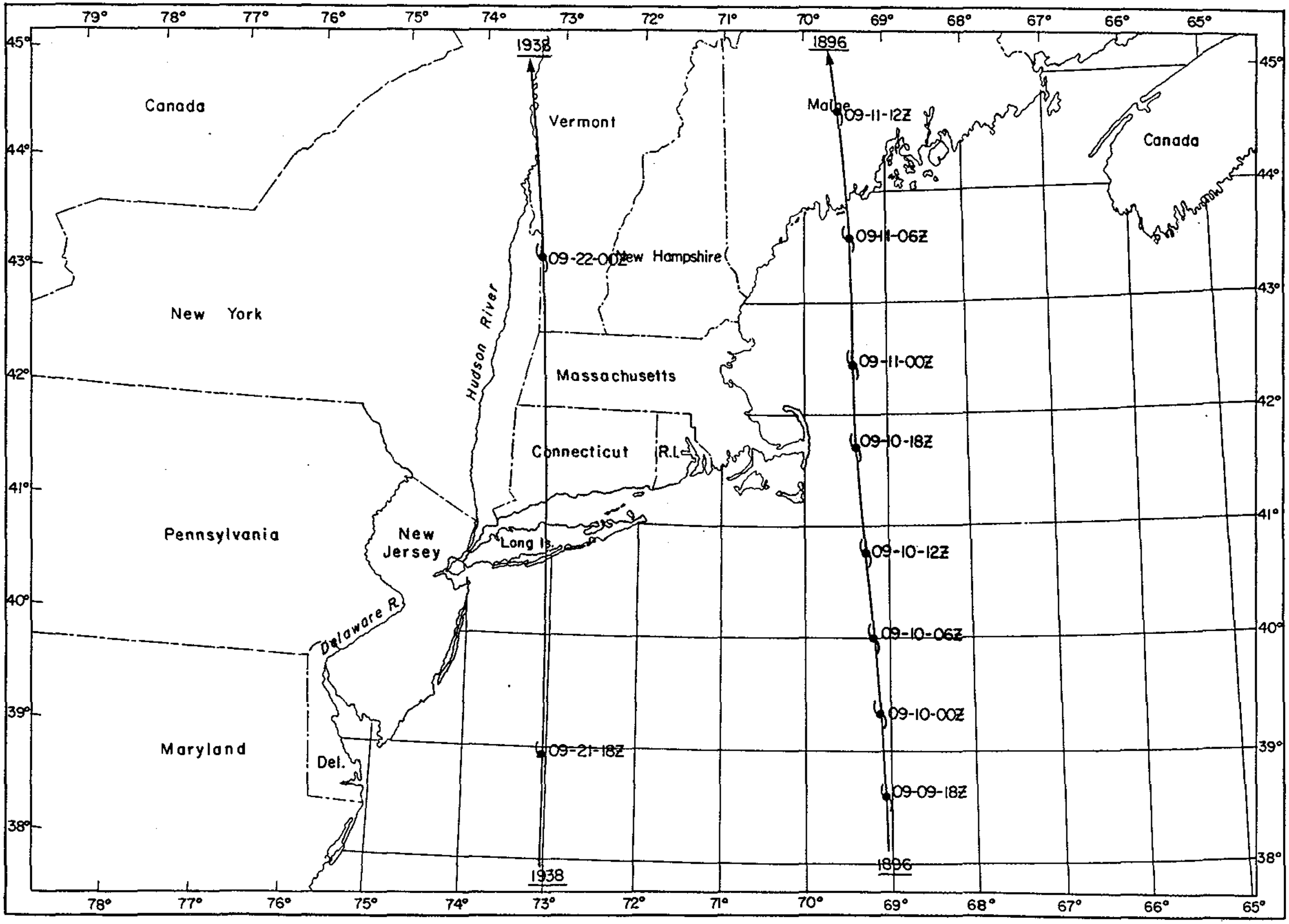
Figure 10. Same as Figure 5, except for northeastbound (NE) storms only. "Landfall points" lie on a perpendicular through Quicksand Point.



TRANSVERSE MERCATOR PROJECTION
SCALE 1: 3, 400, 000
TRUE AT 71W

NARRAGANSETT-BUZZARDS BAYS

FIGURE 1.



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Long Is.
Delaware R.
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09-11-06Z
09-22-00Z
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09-21-18Z
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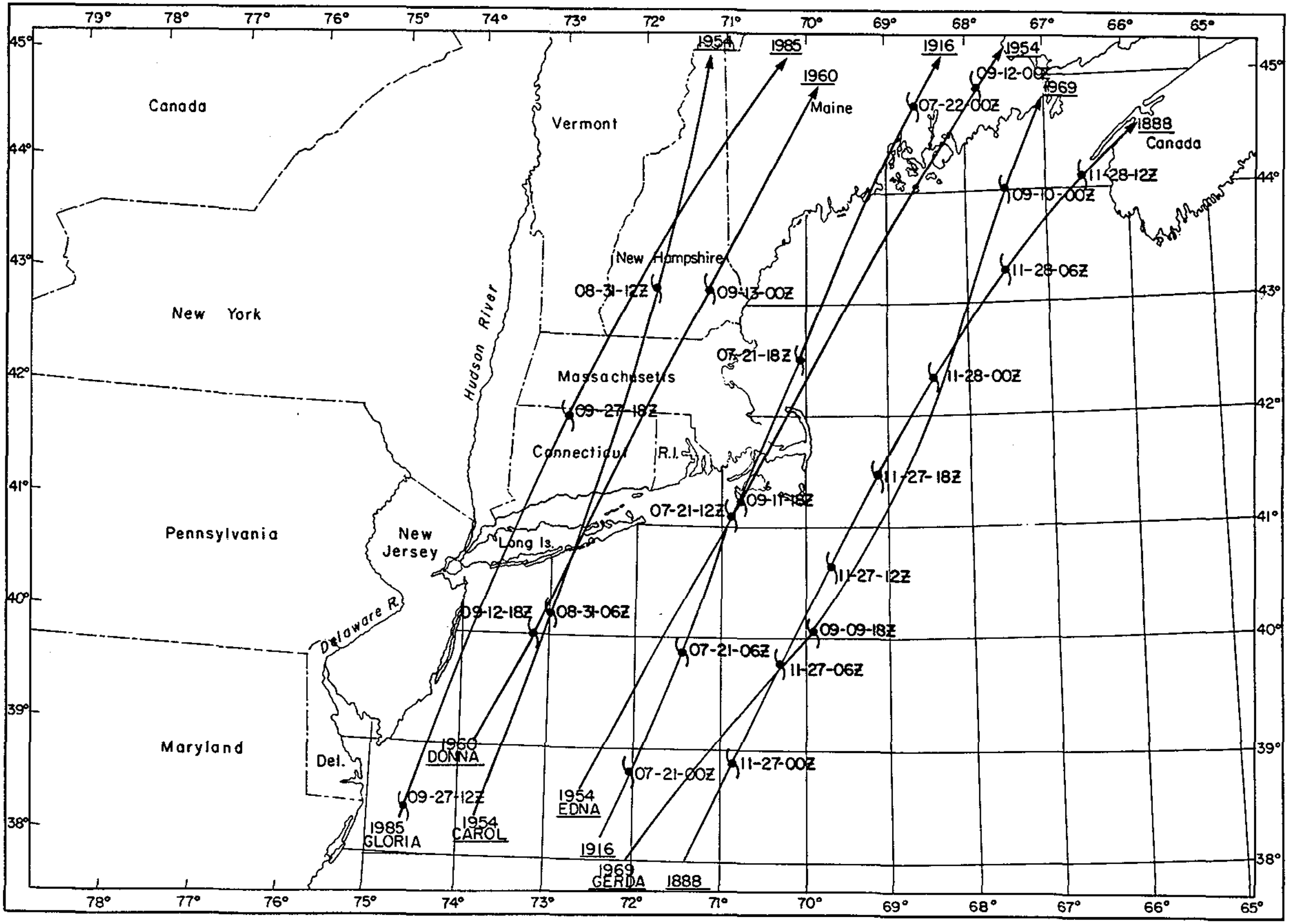
FIGURE 2.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07-21-06Z
11-27-06Z
1960 DONNA
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FIGURE 3.

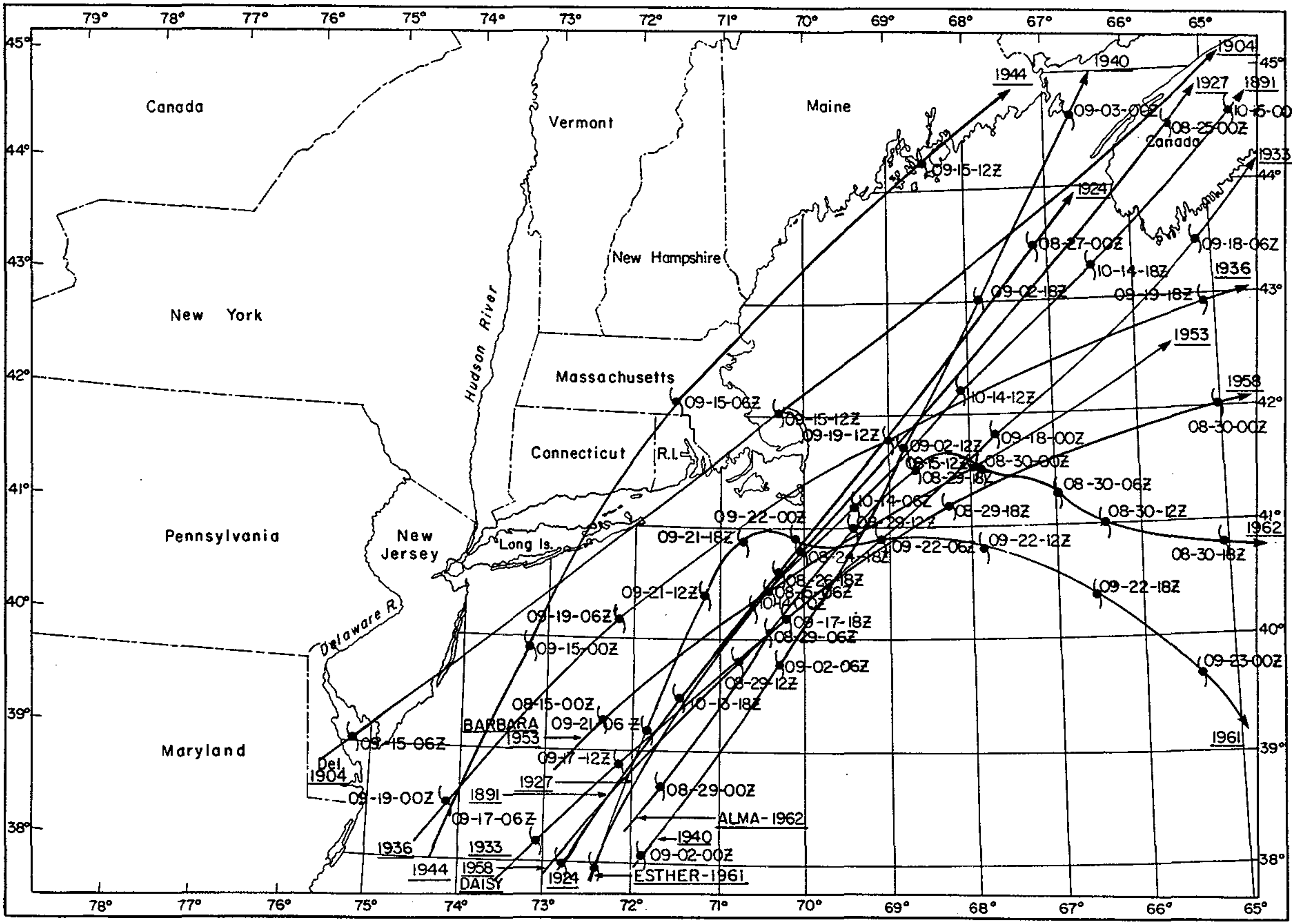

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FIGURE 4.

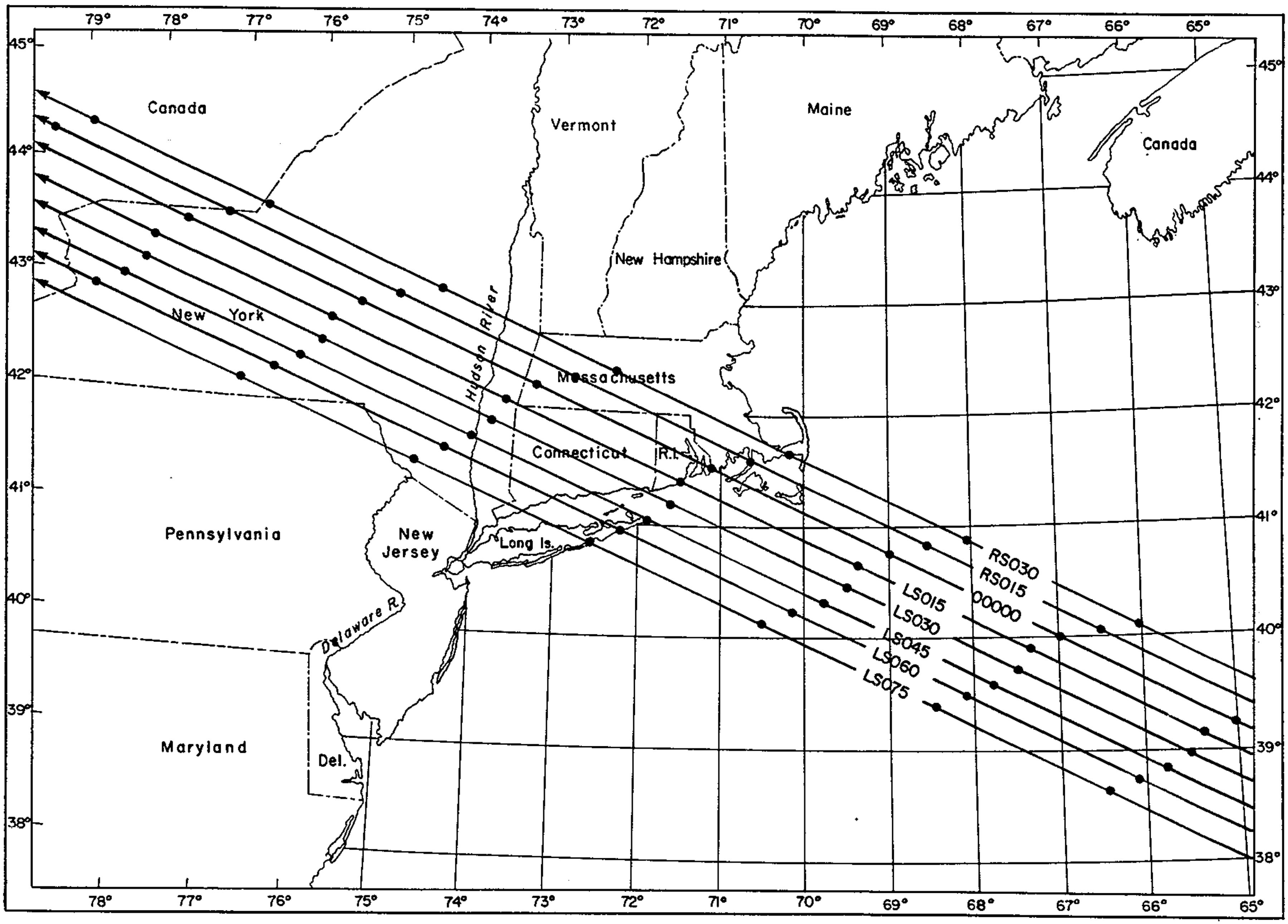

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FIGURE 5.

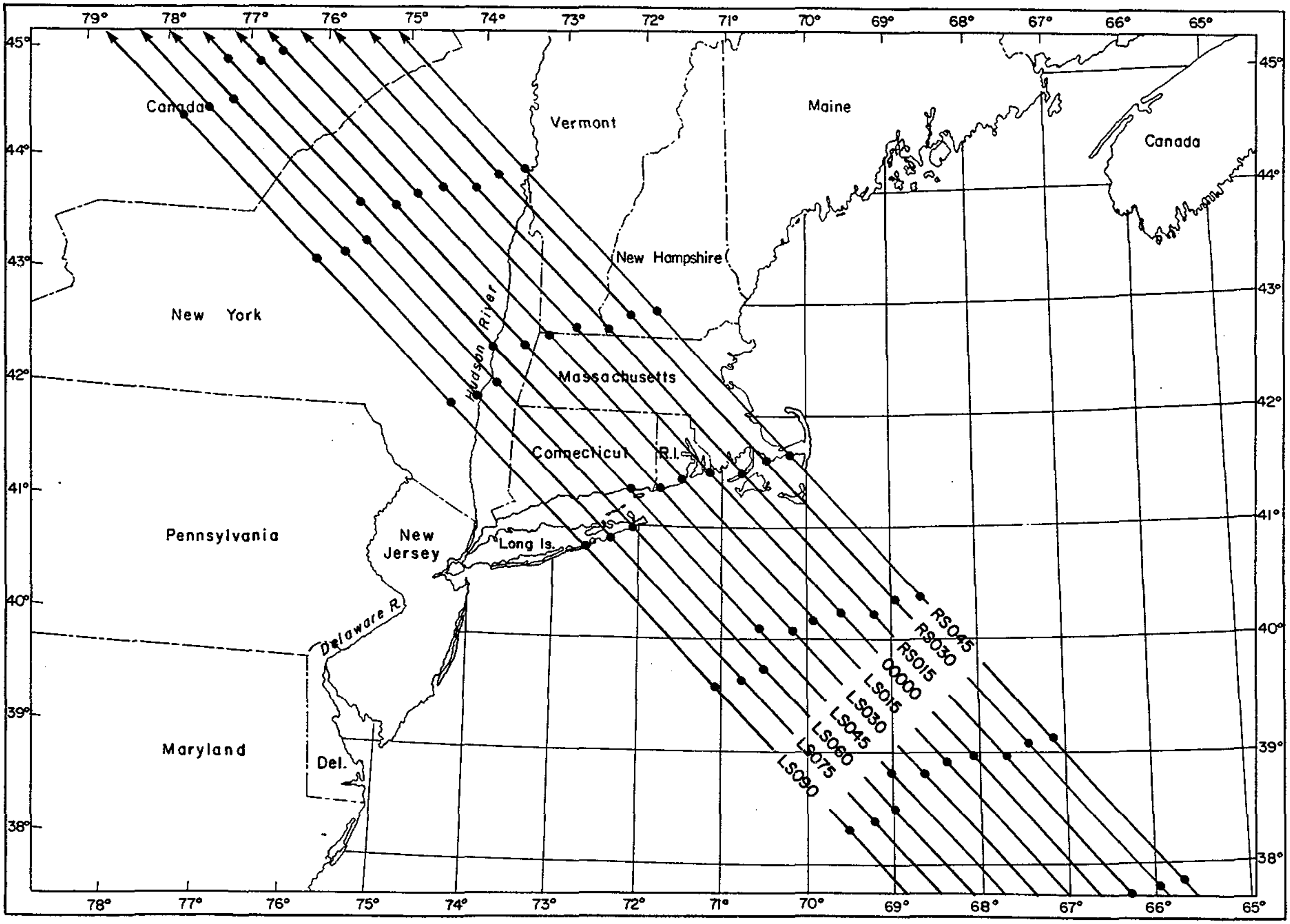

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FIGURE 6.

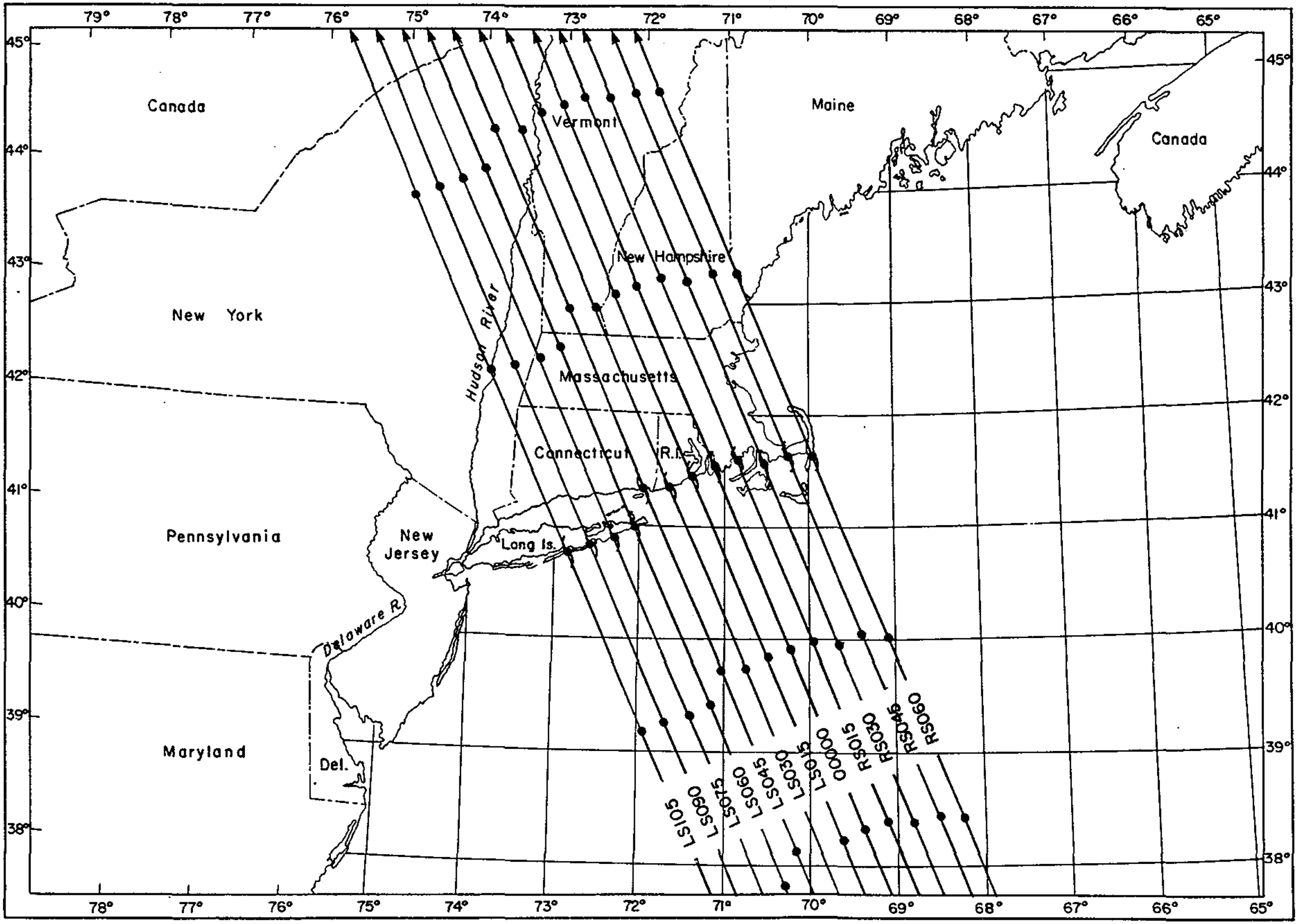
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FIGURE 7.

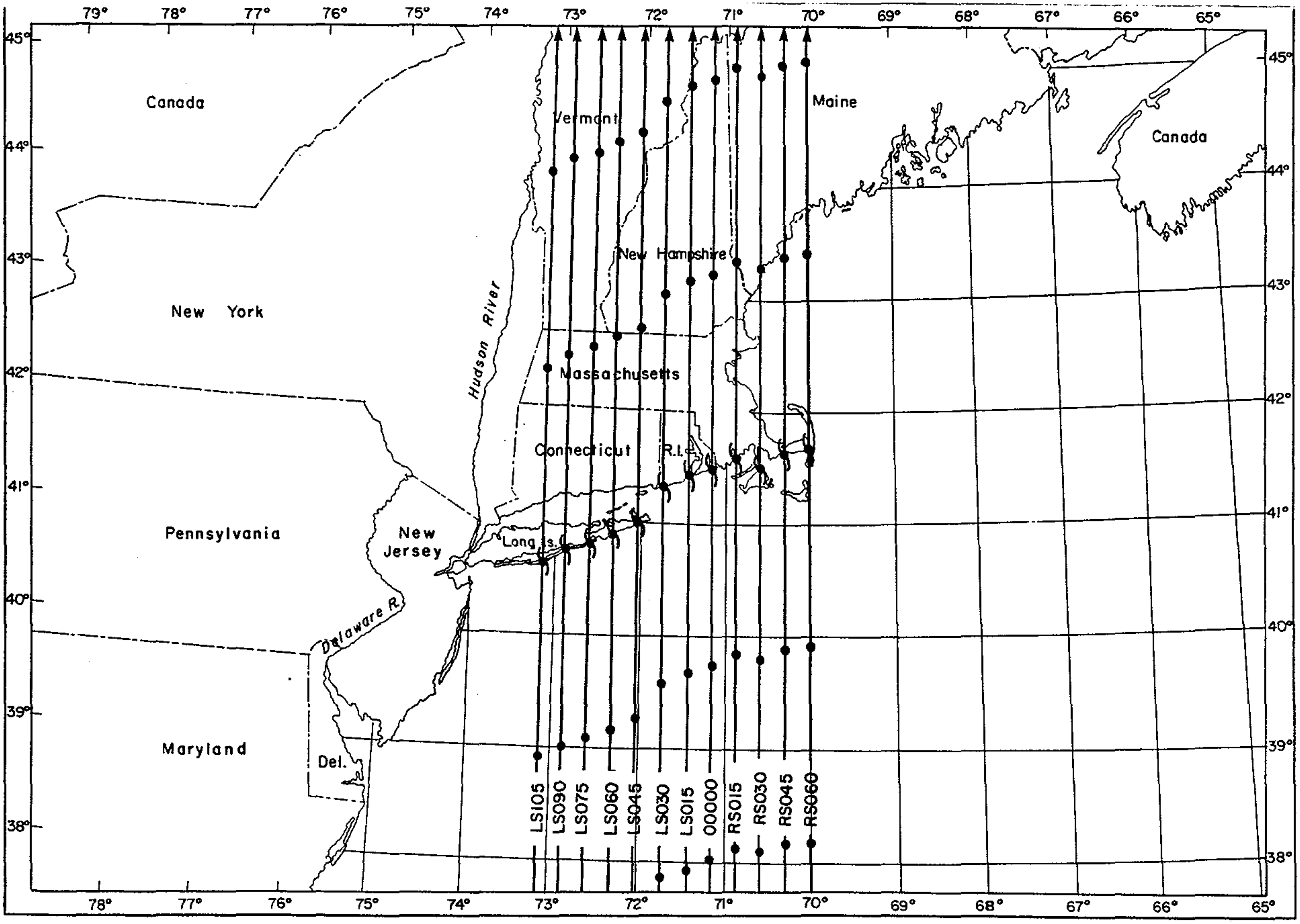
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FIGURE 8.

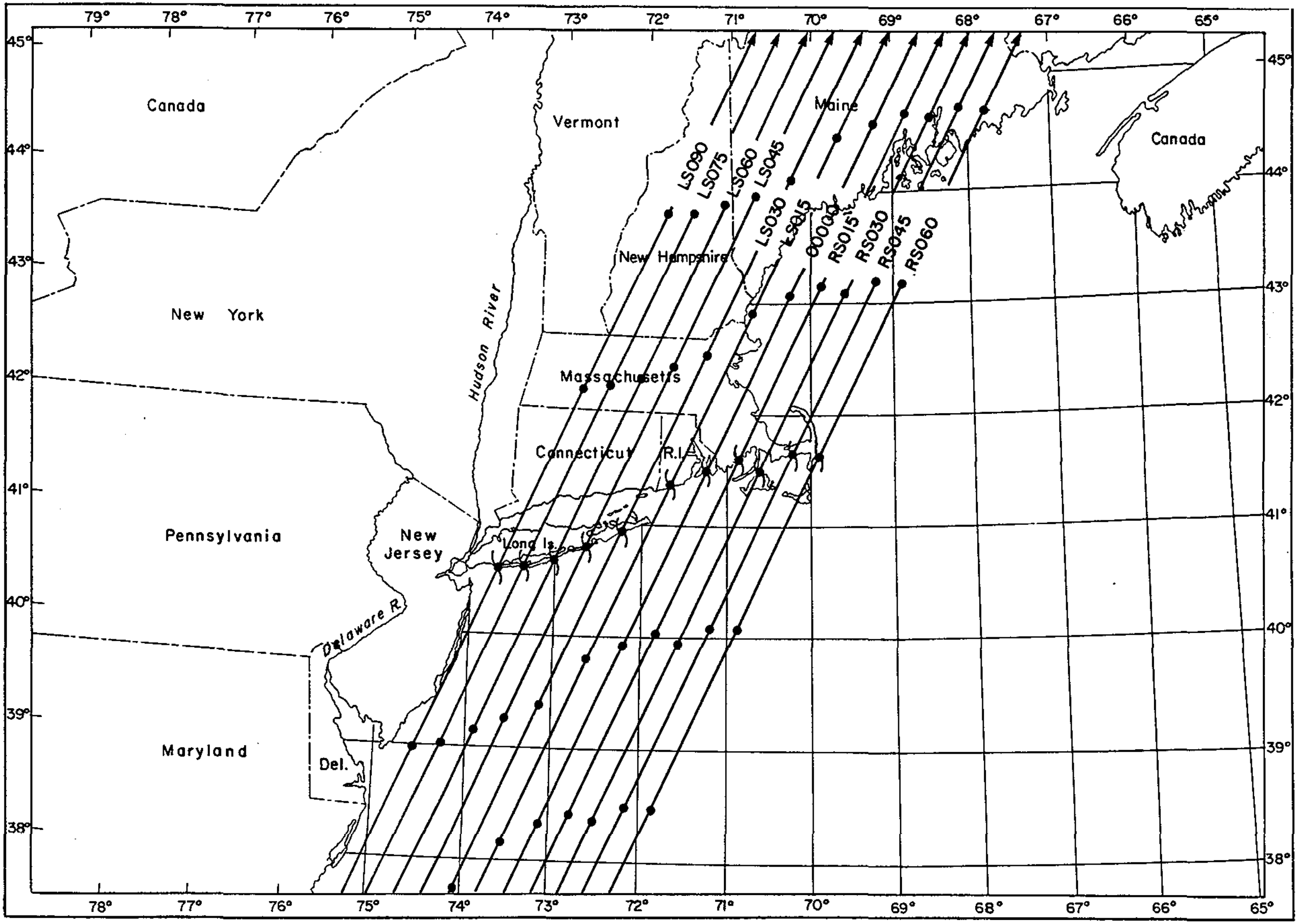

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FIGURE 9.

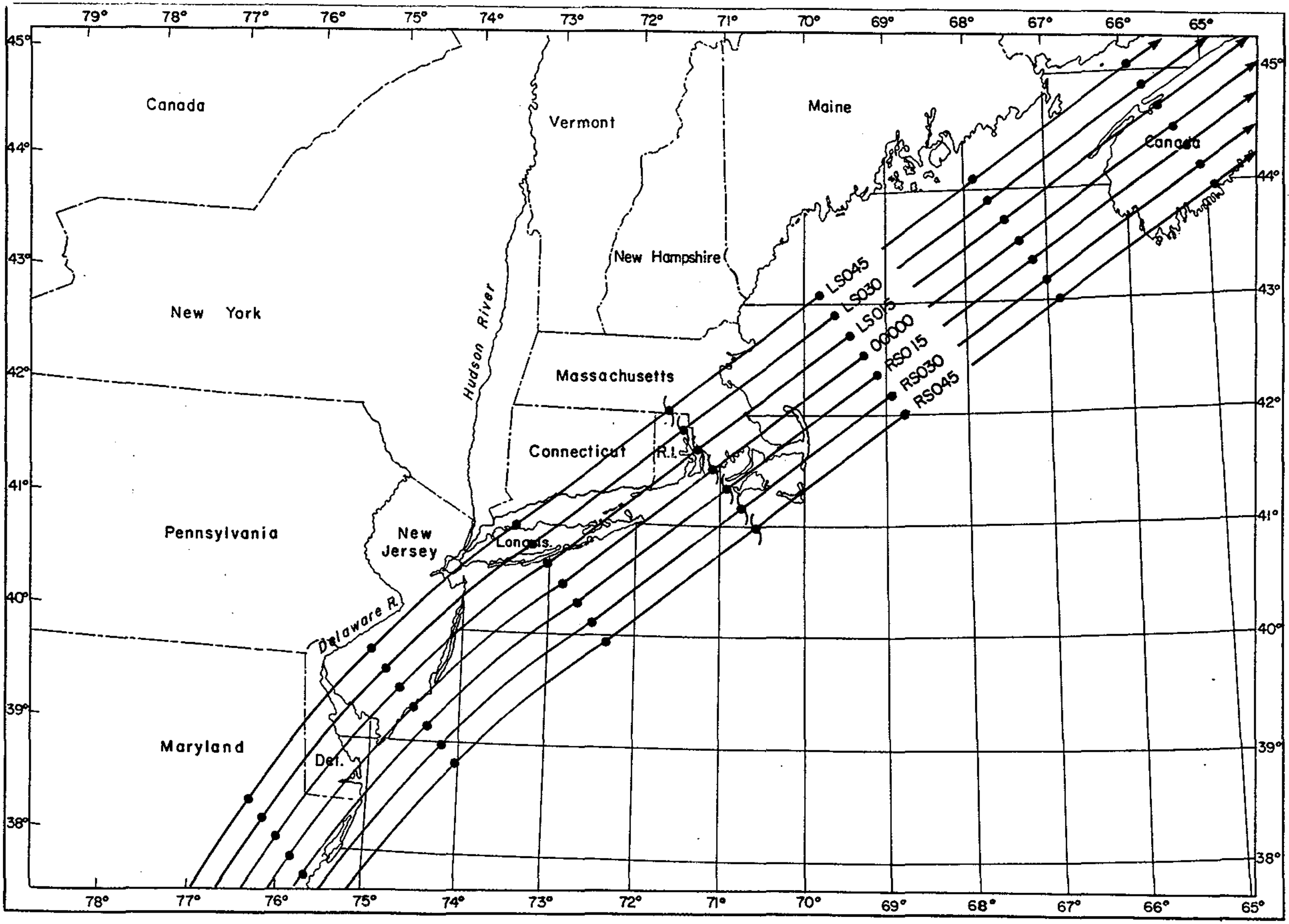

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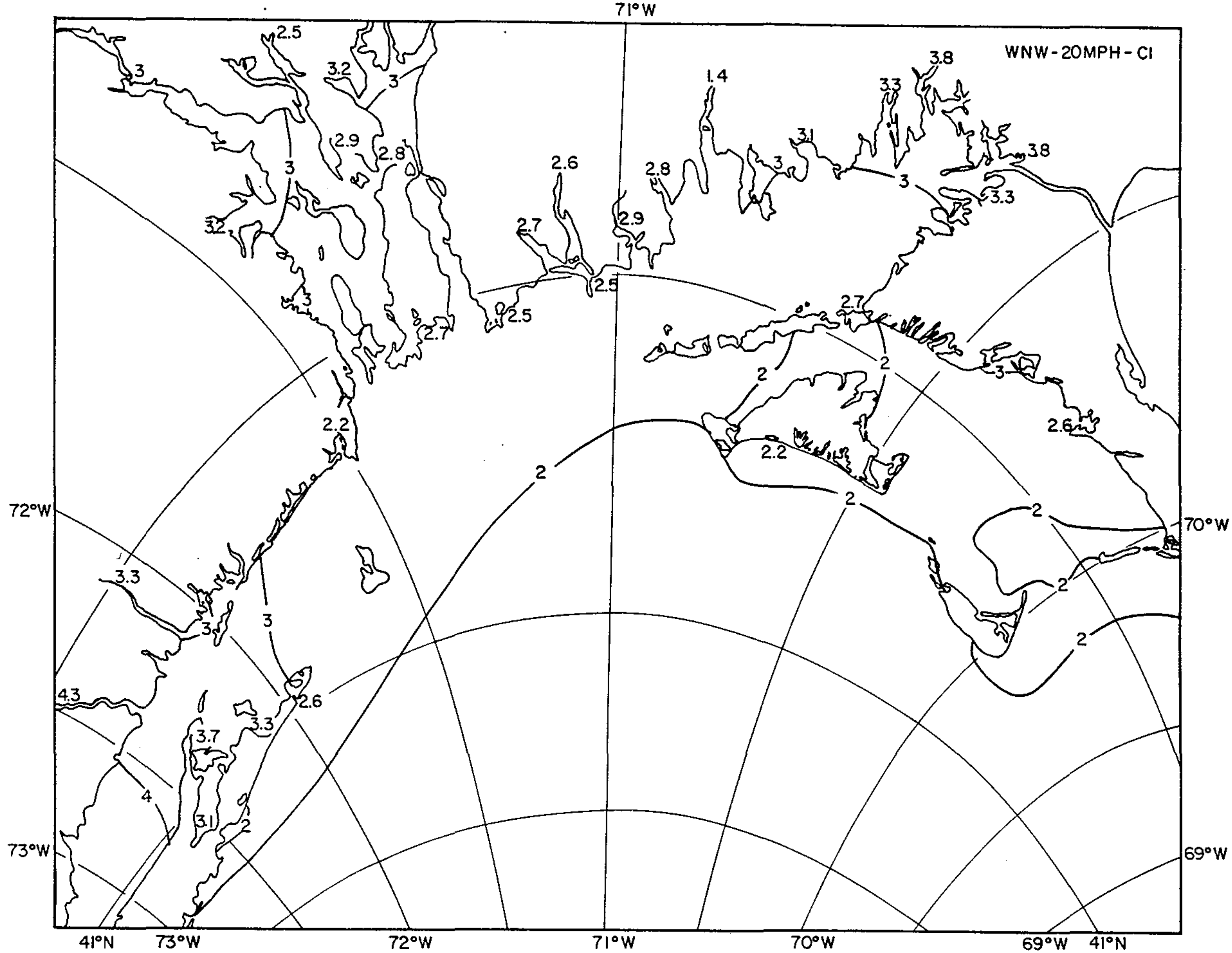
FIGURE 10.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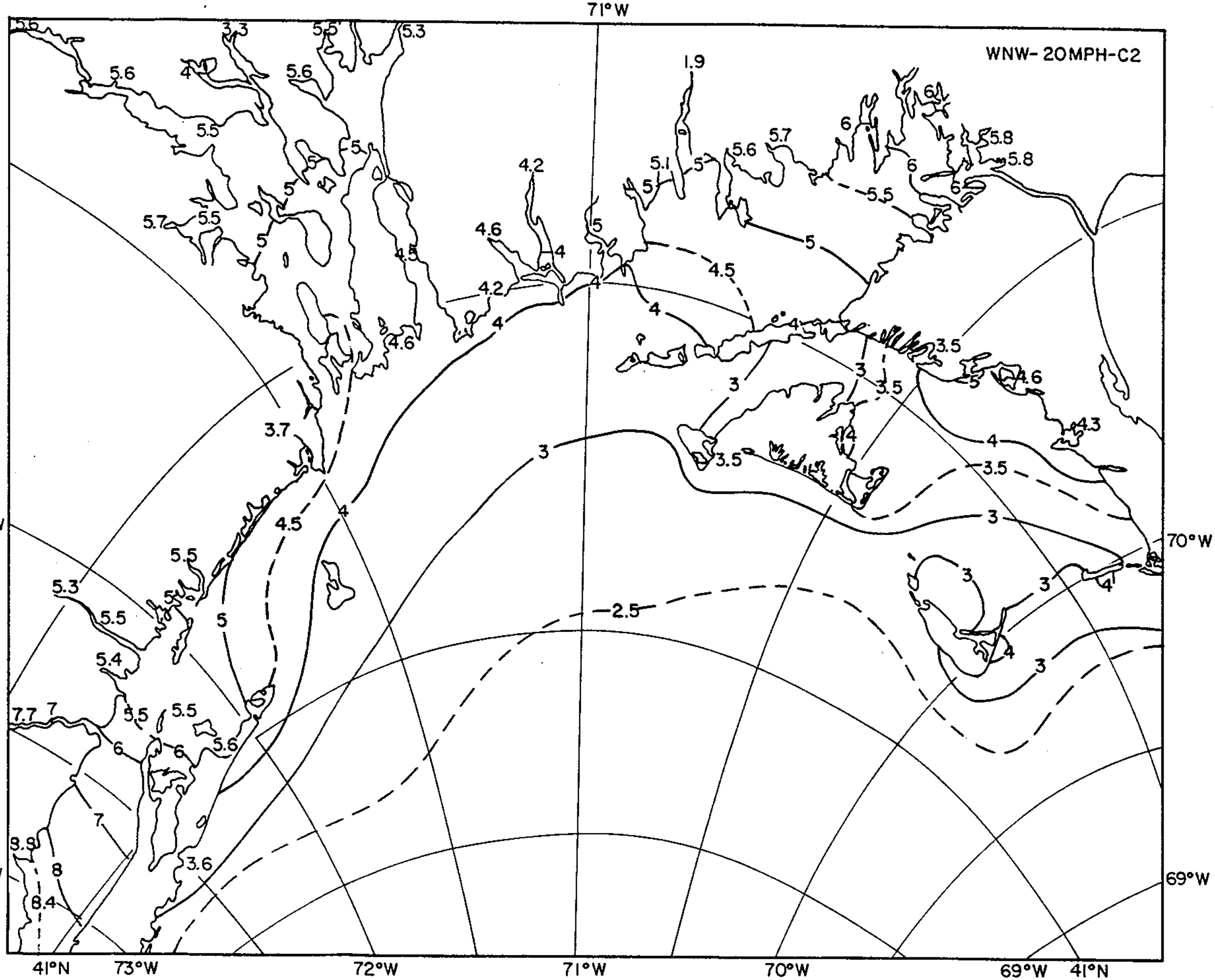
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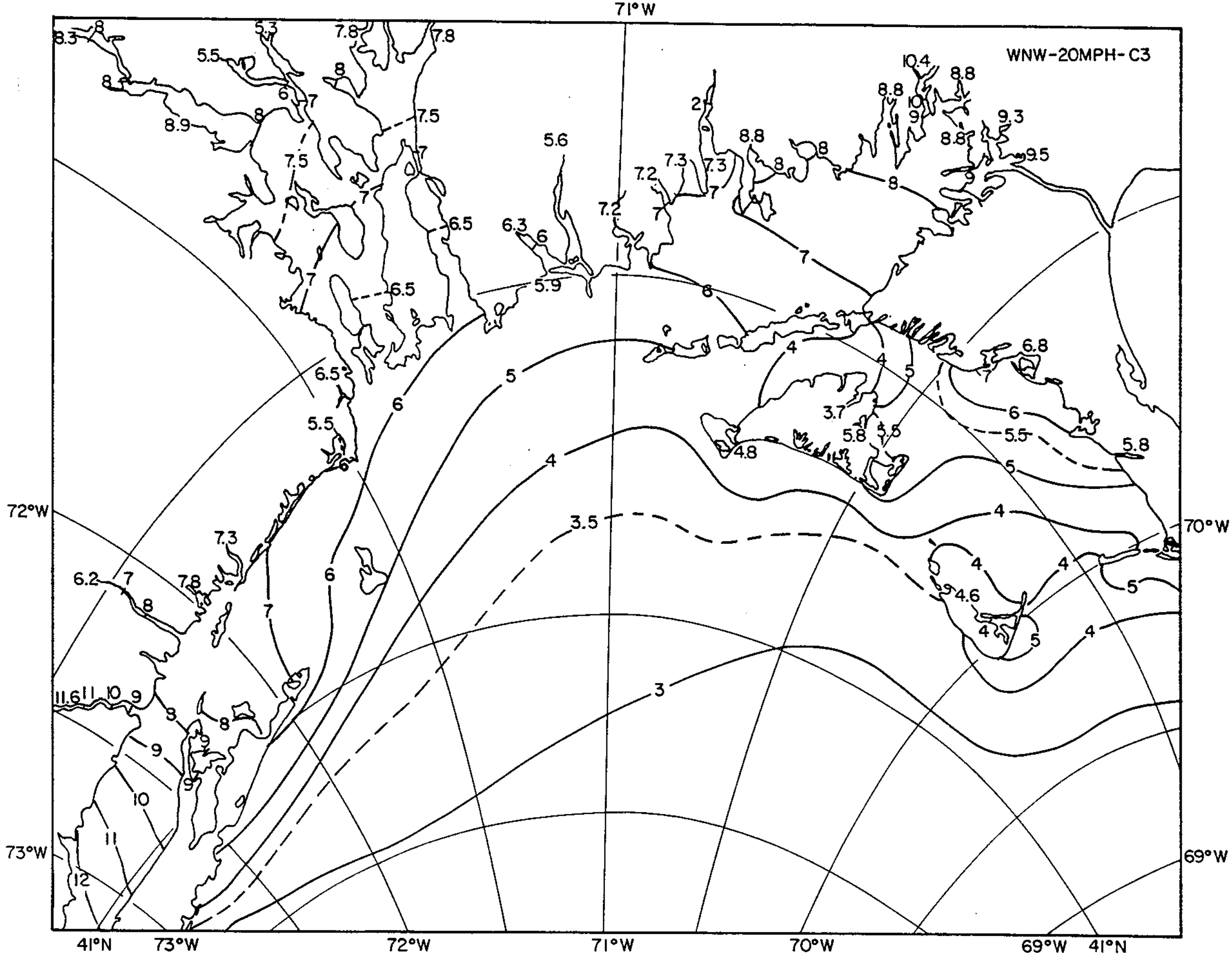
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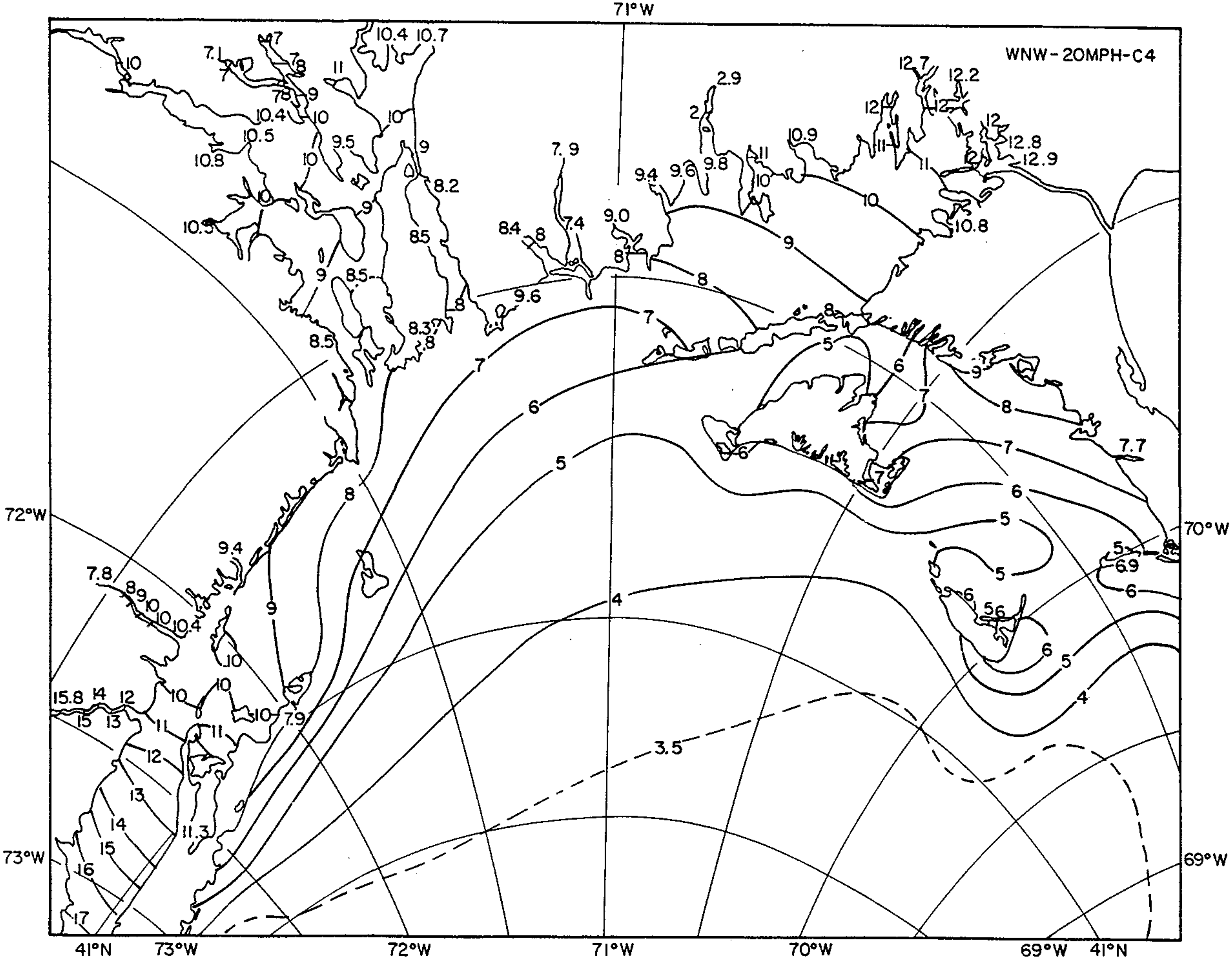
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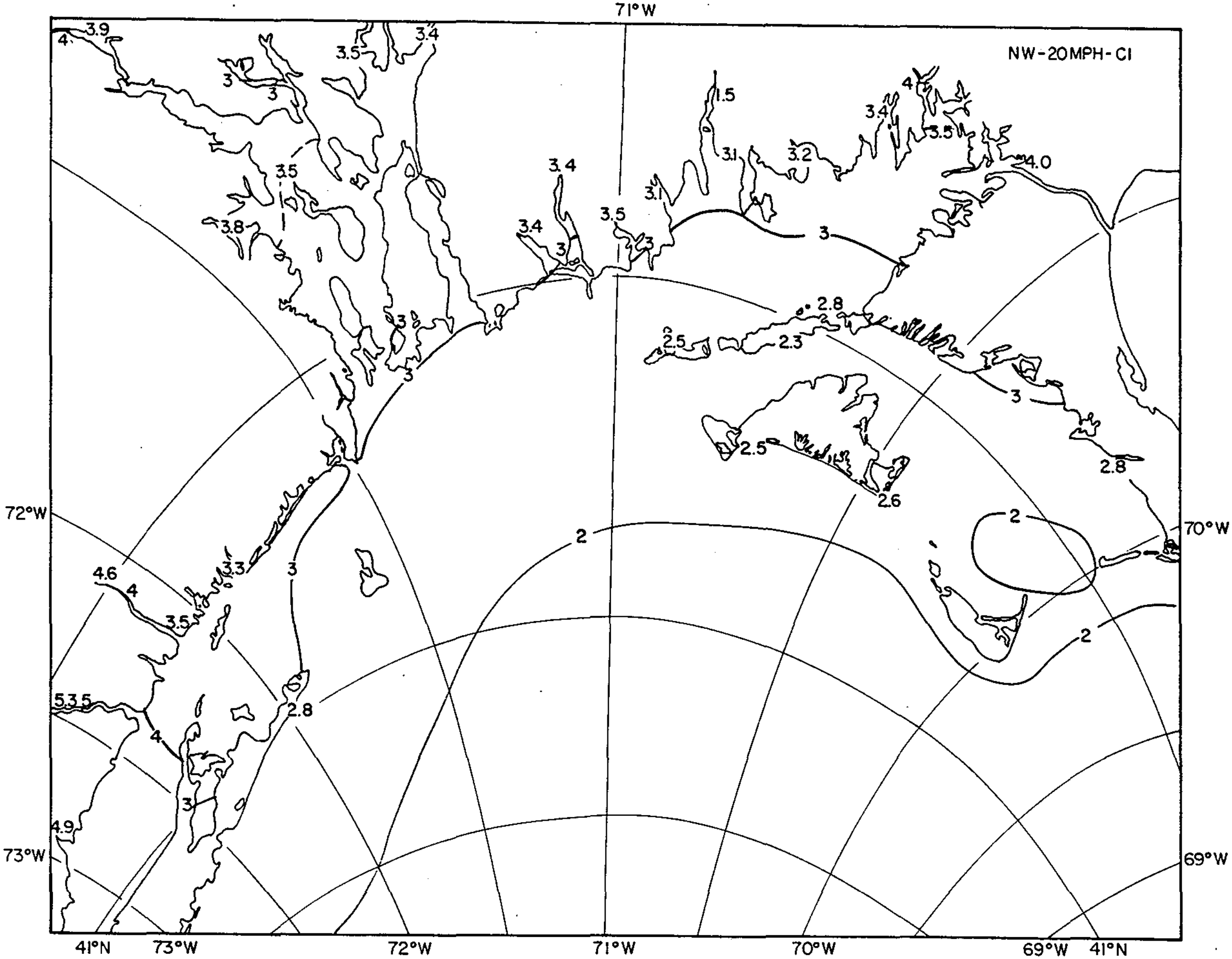
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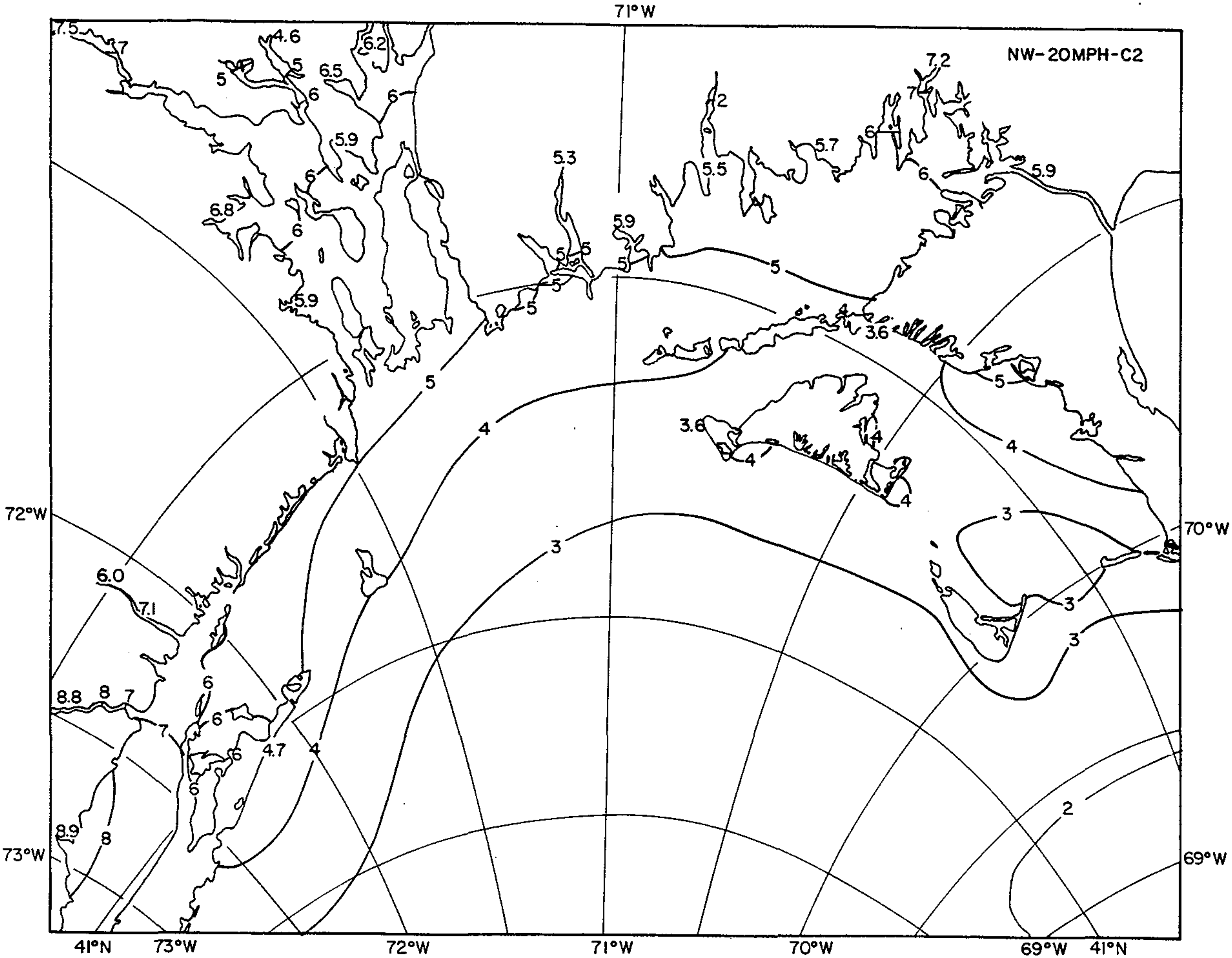
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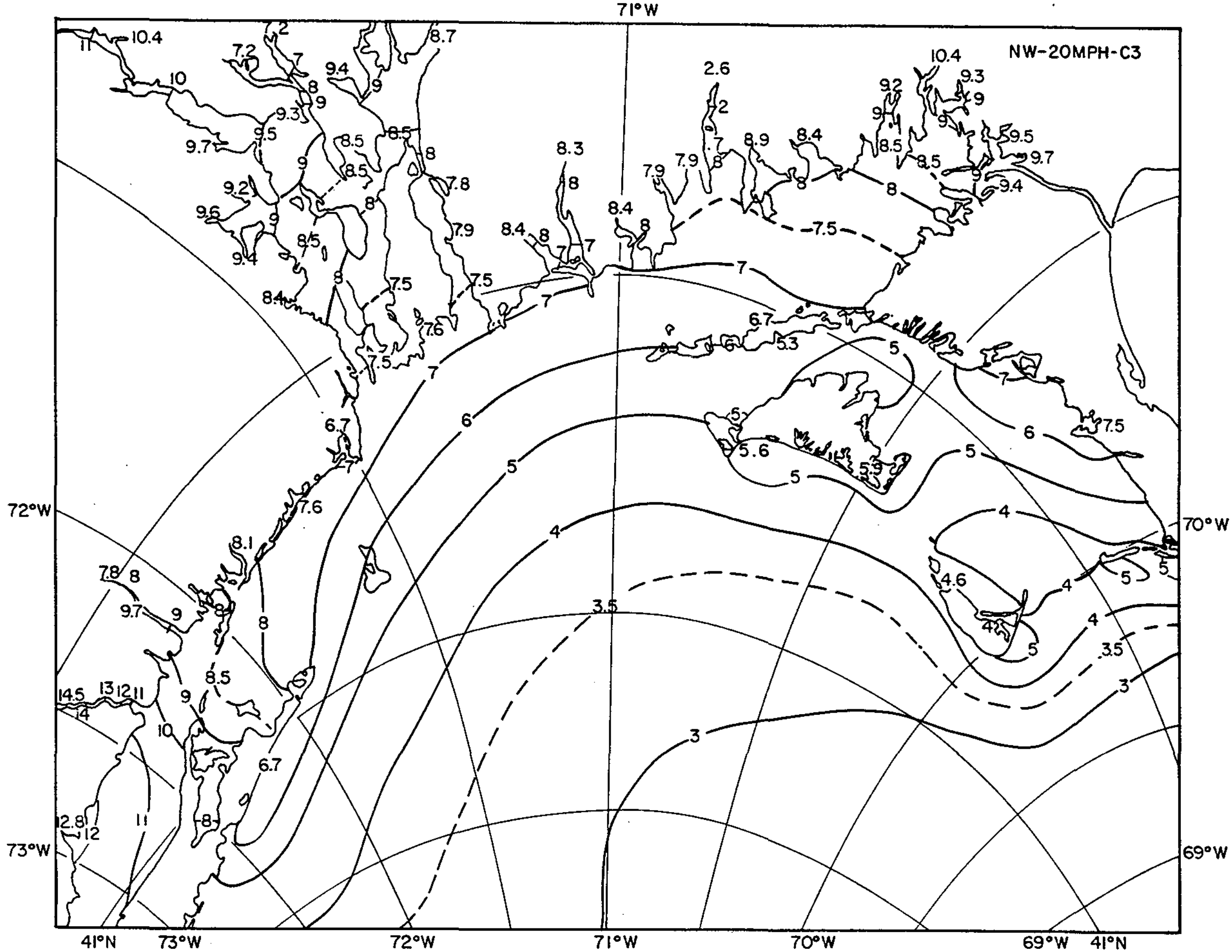

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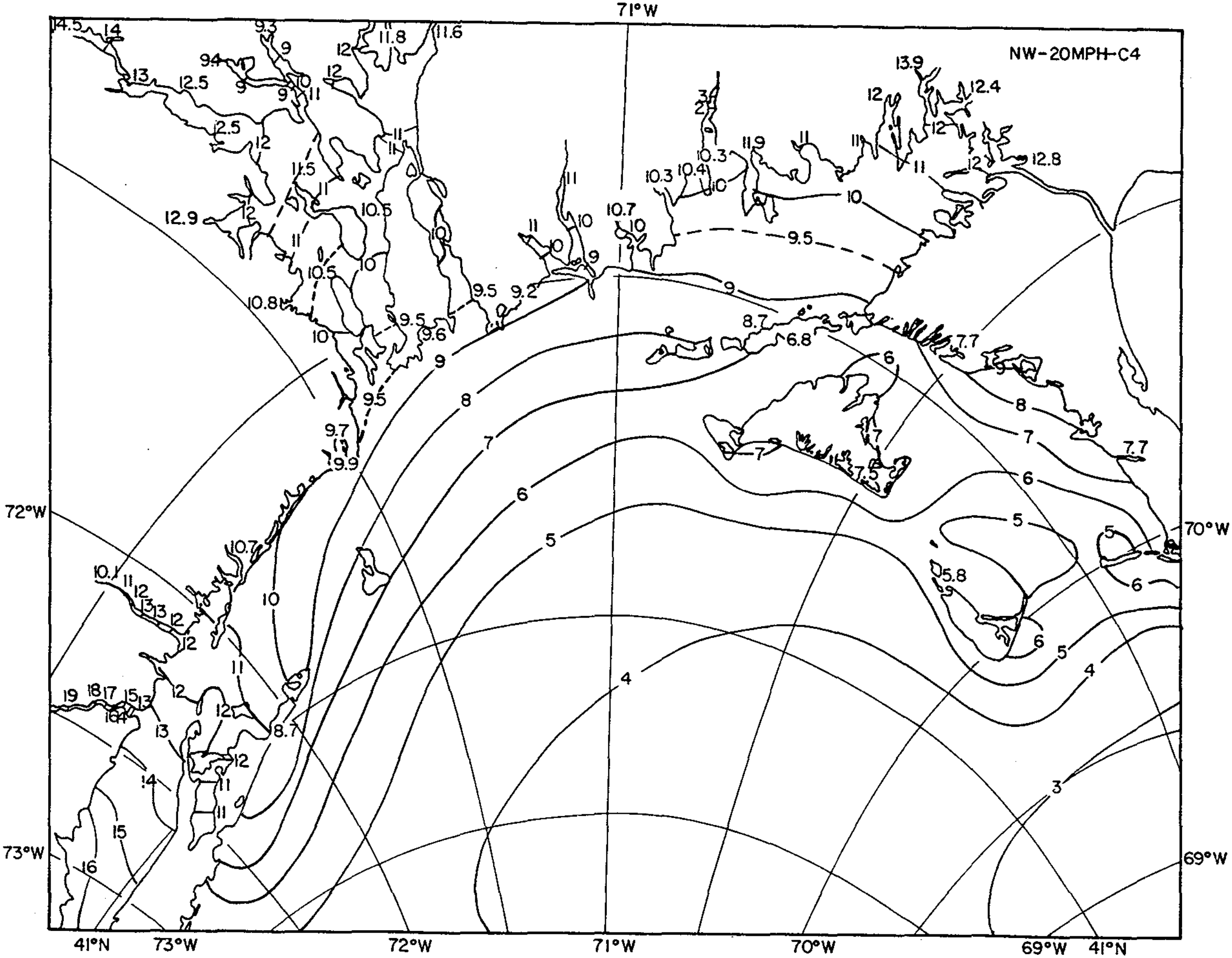
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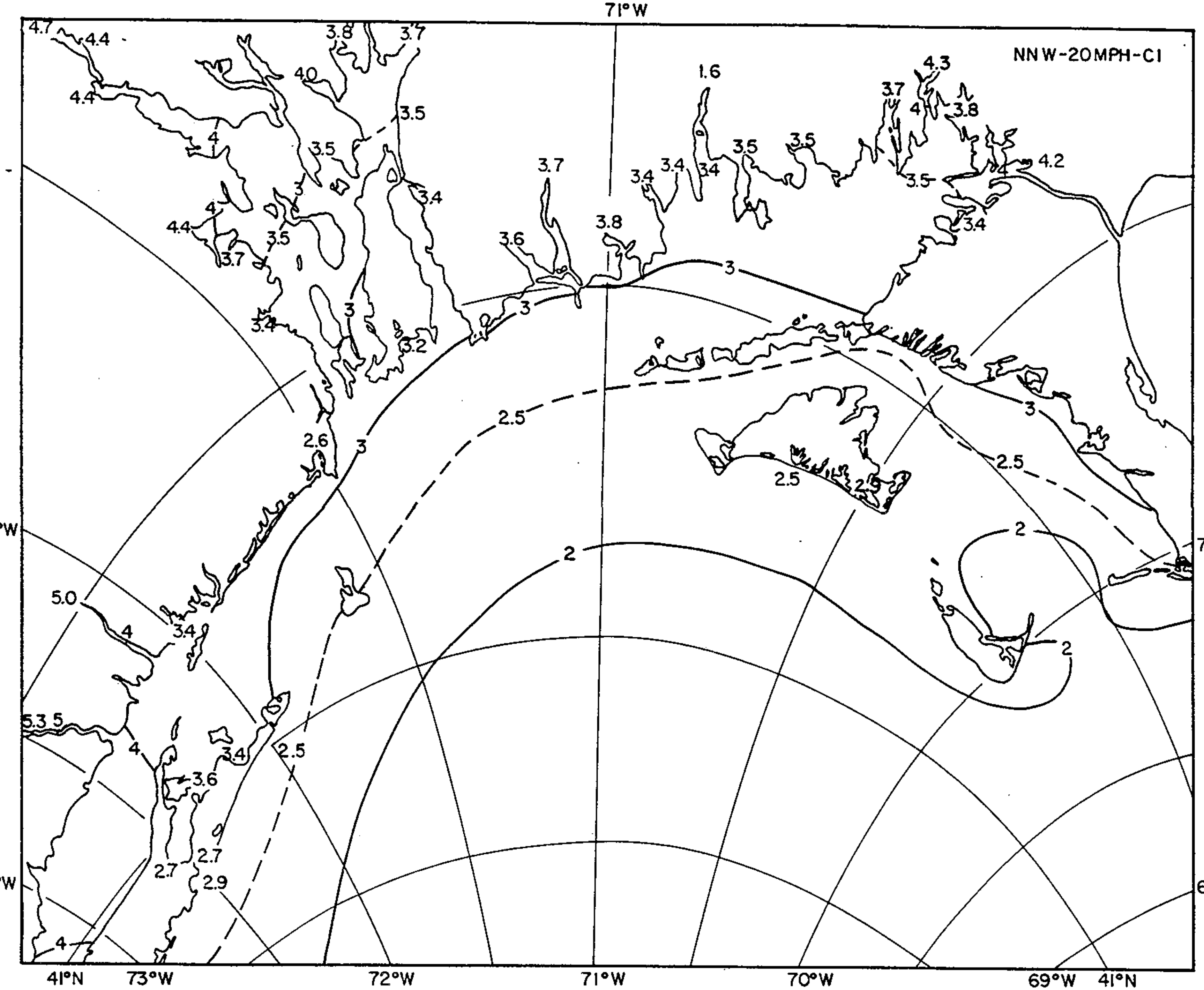
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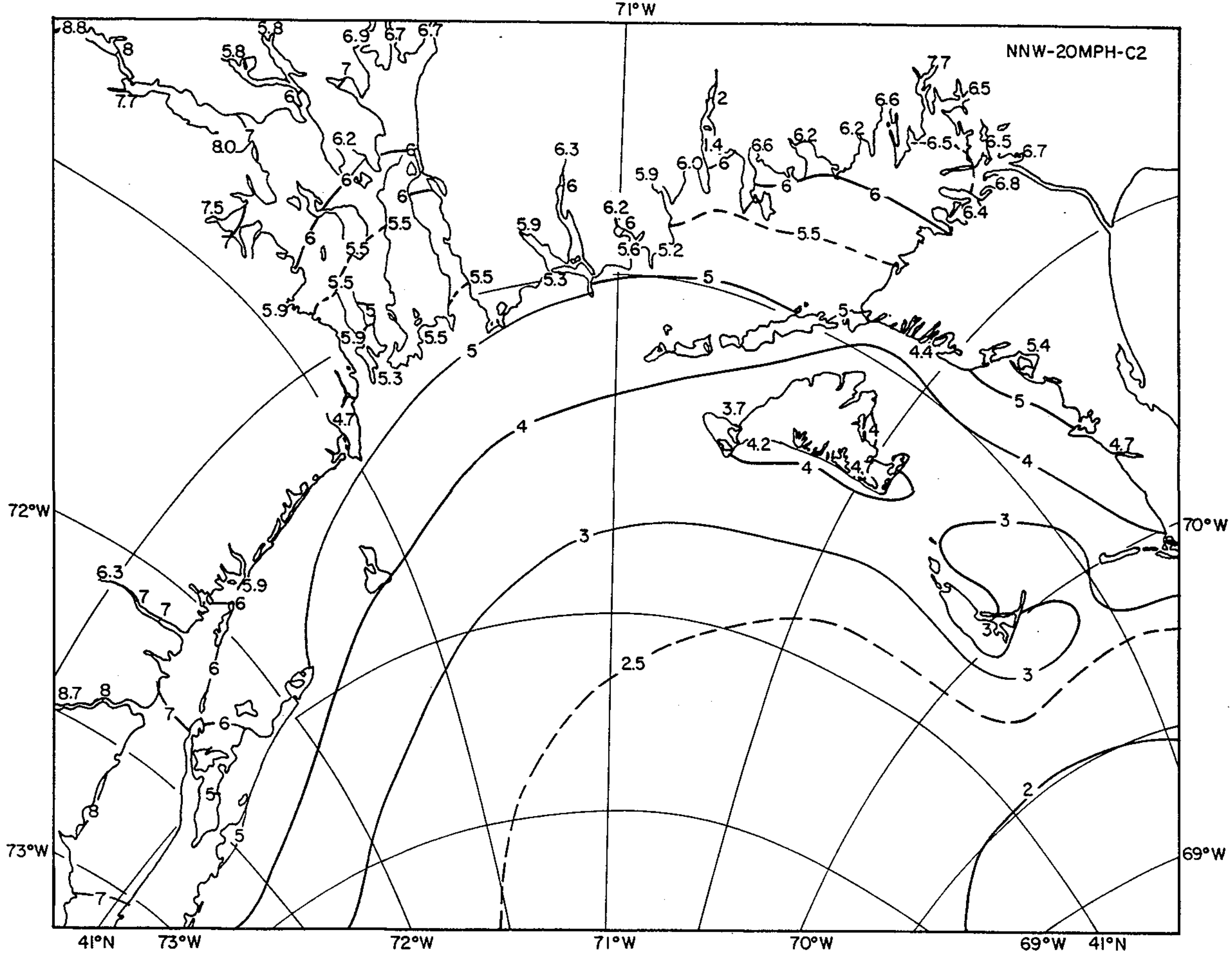
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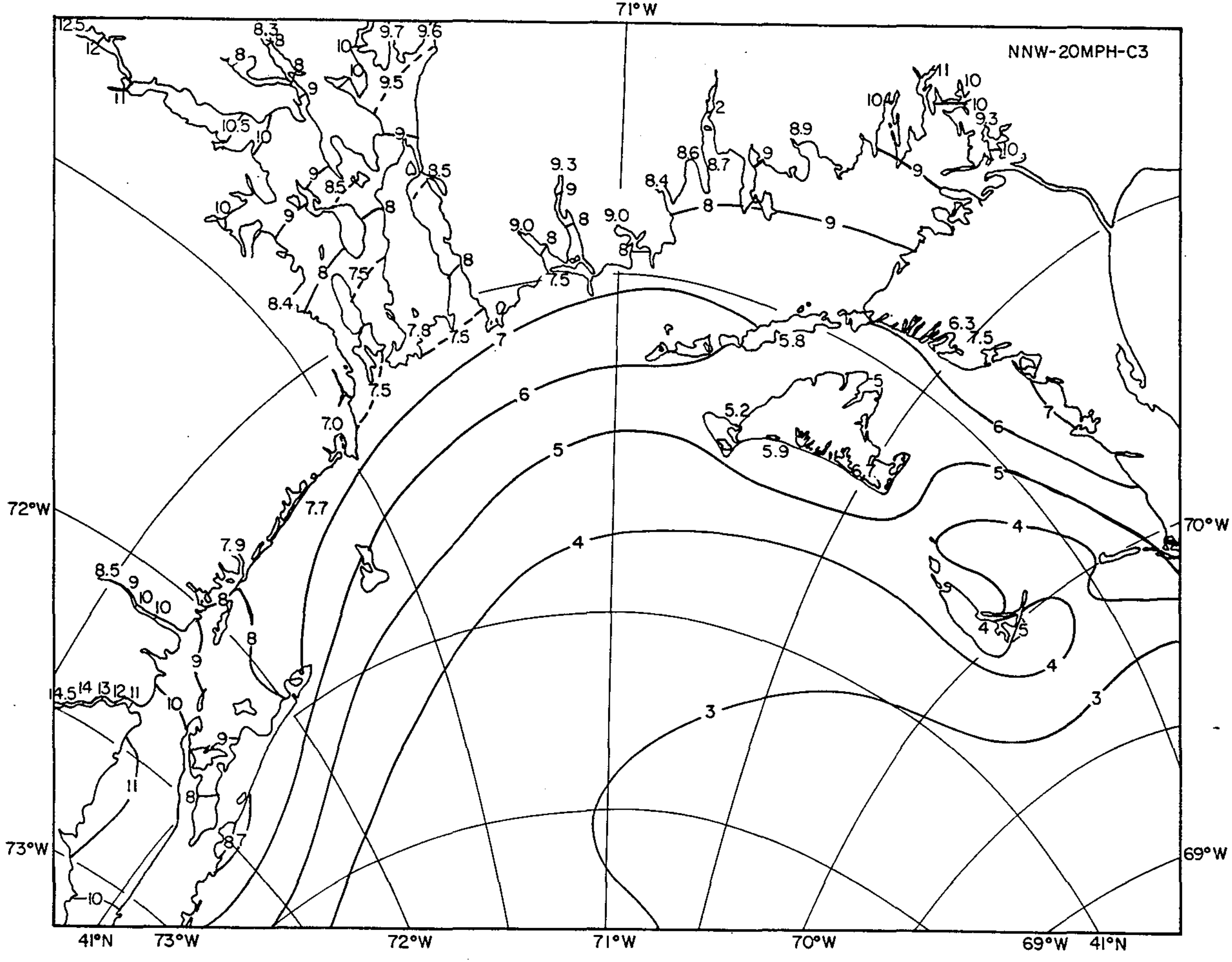
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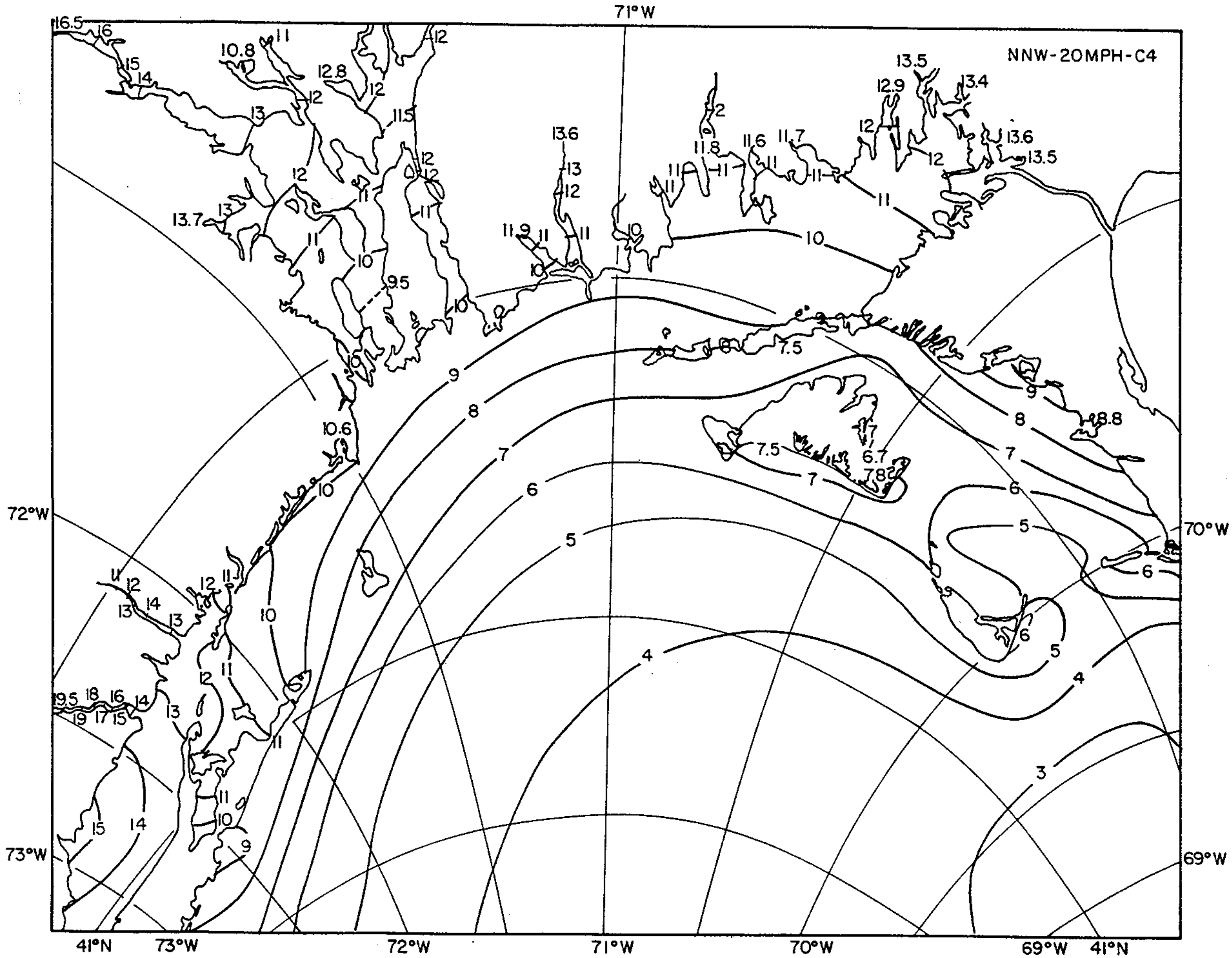
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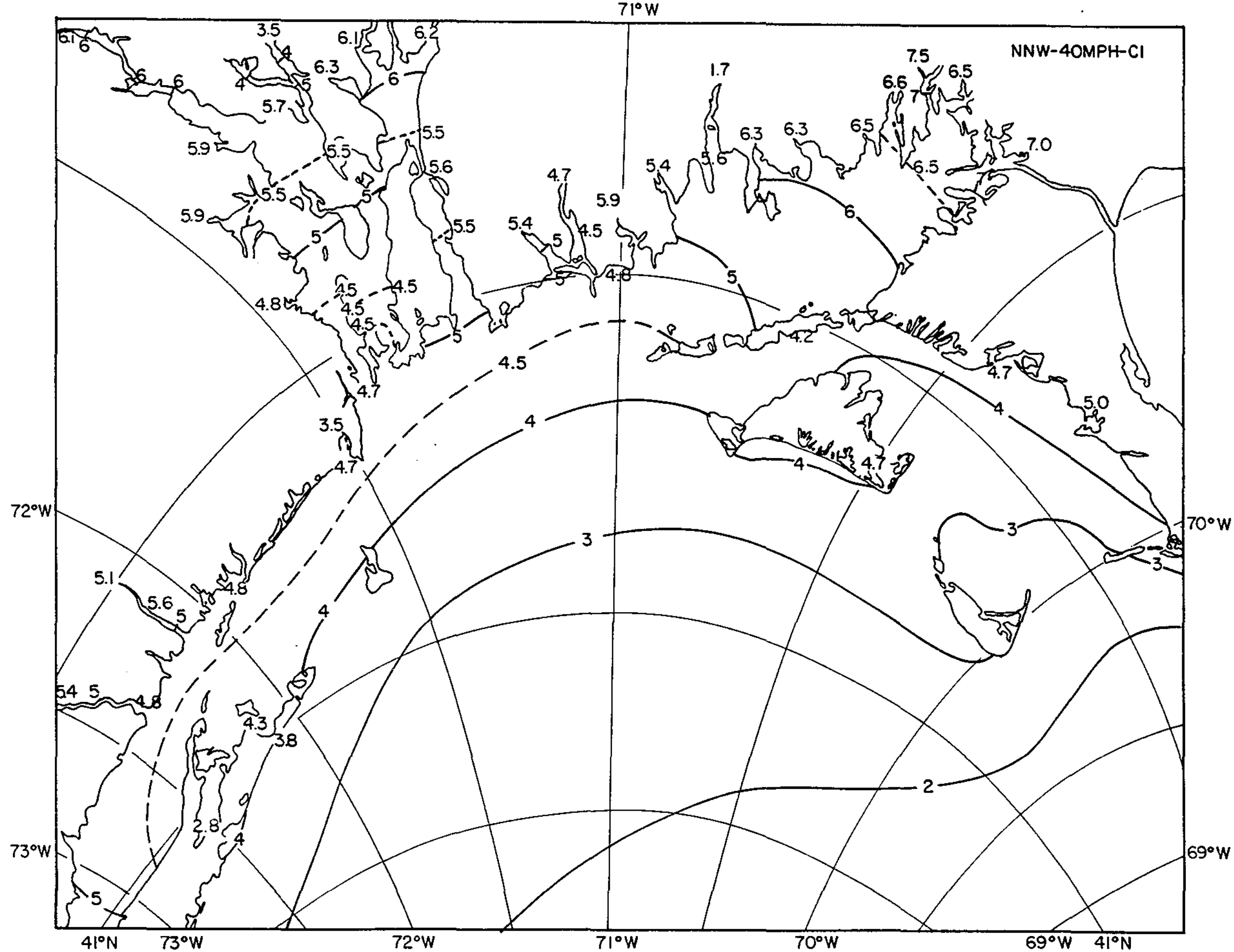
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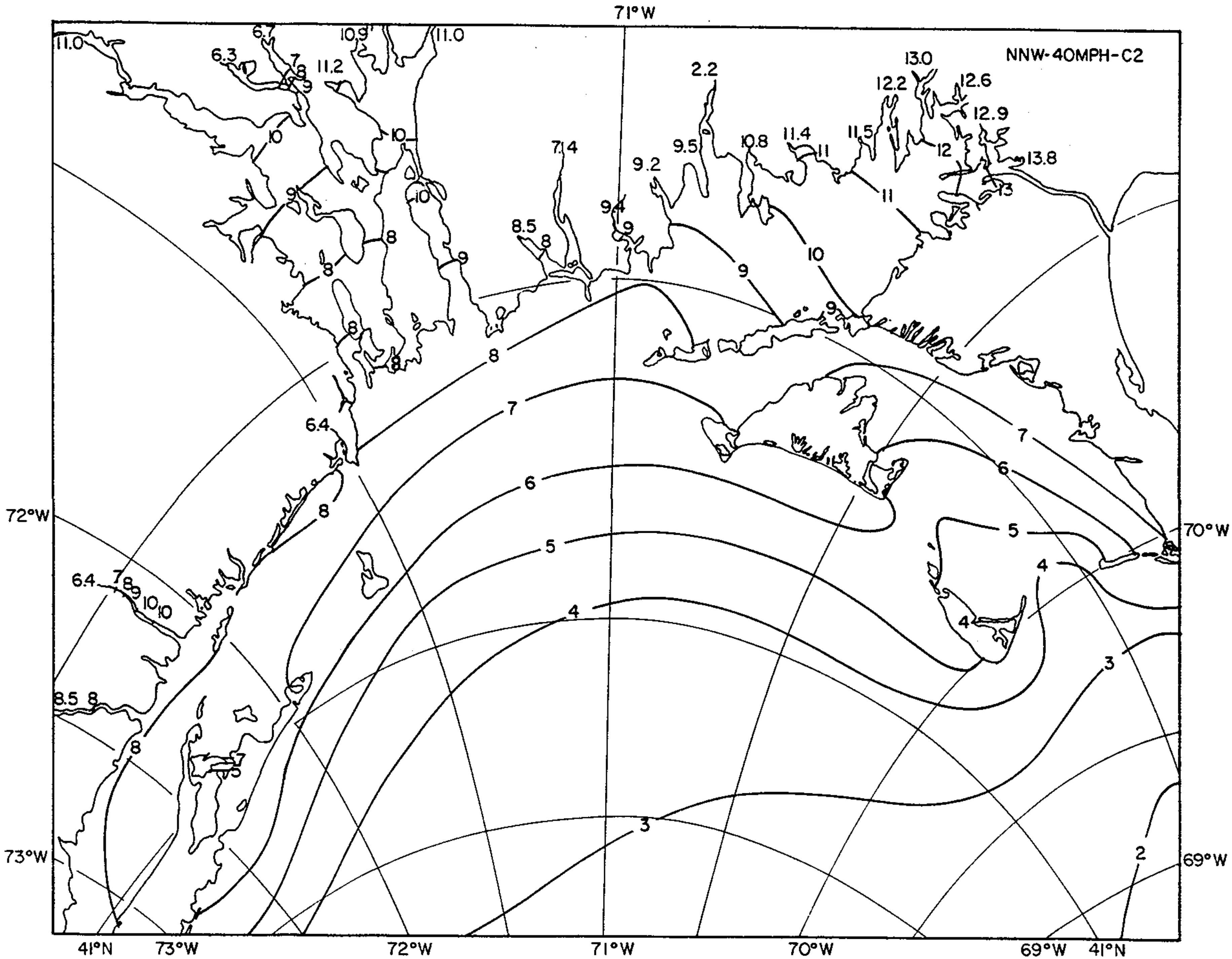
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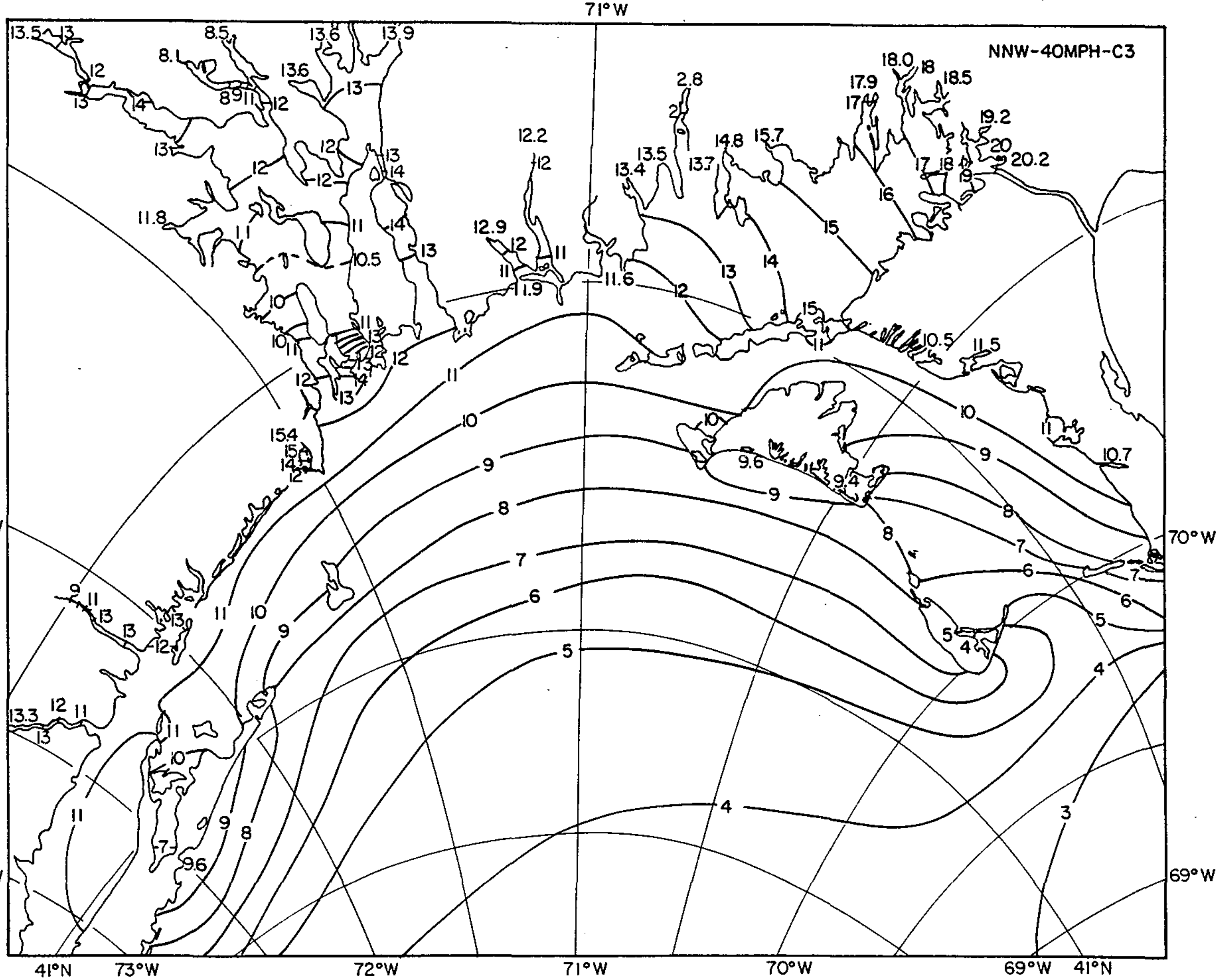
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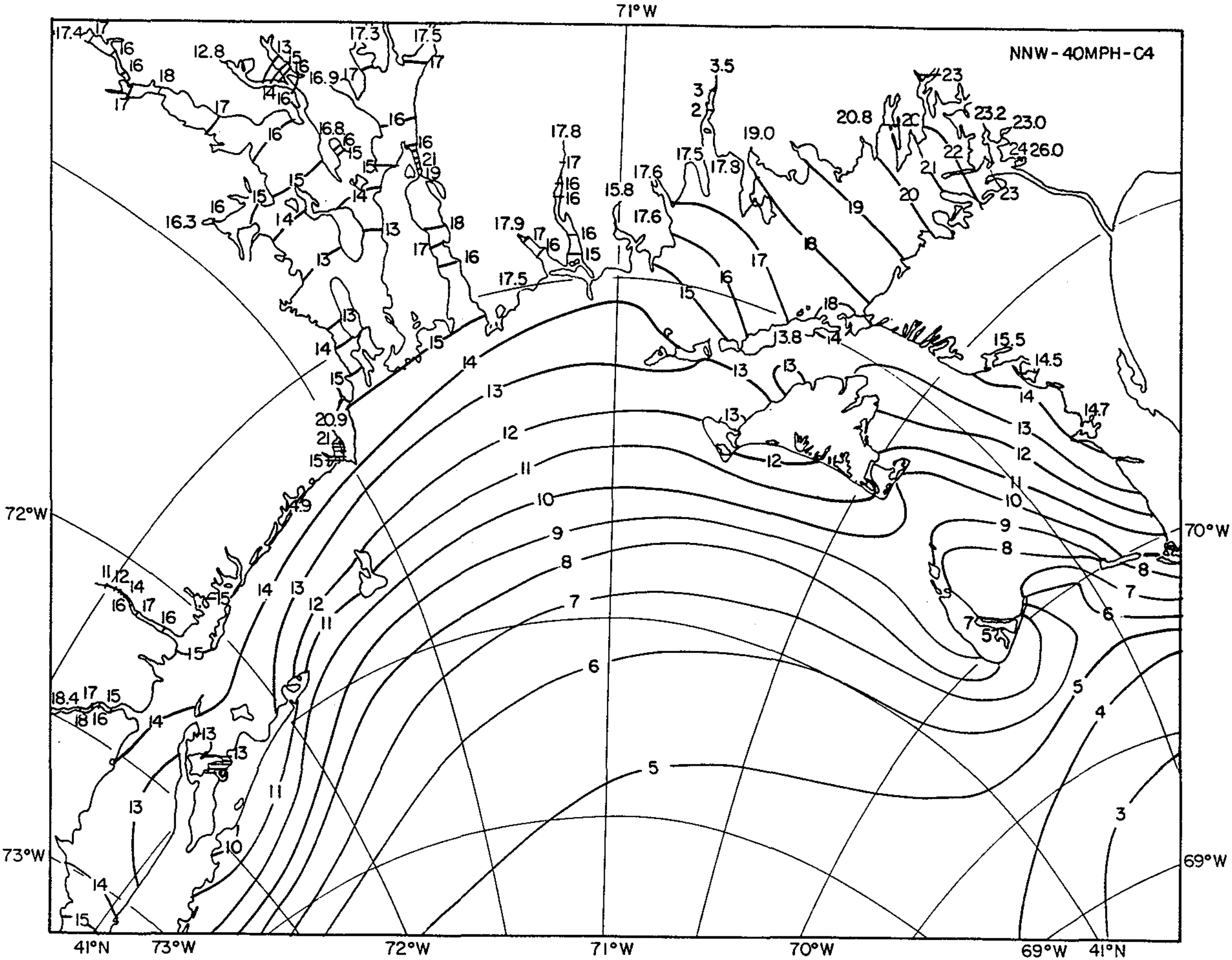
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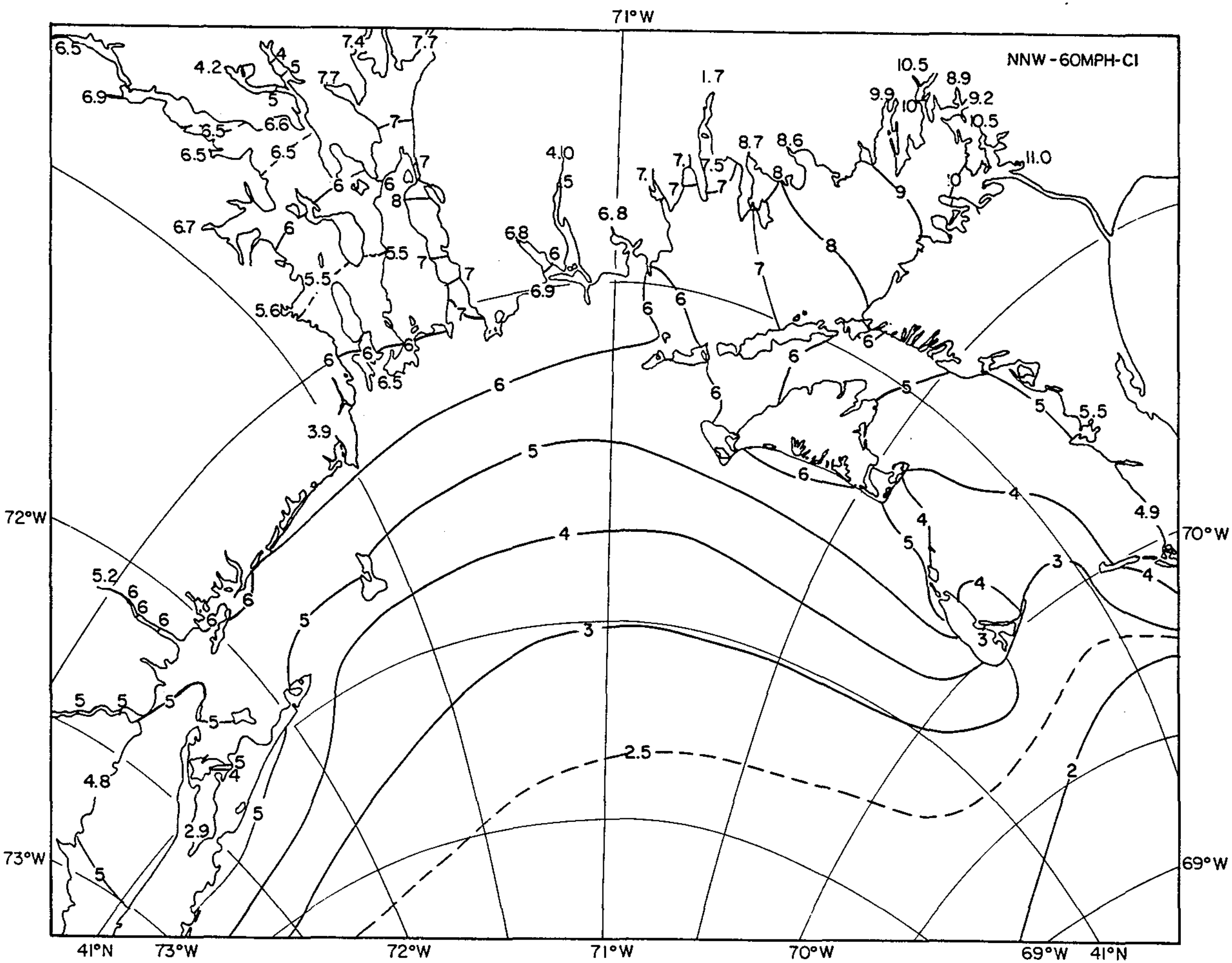
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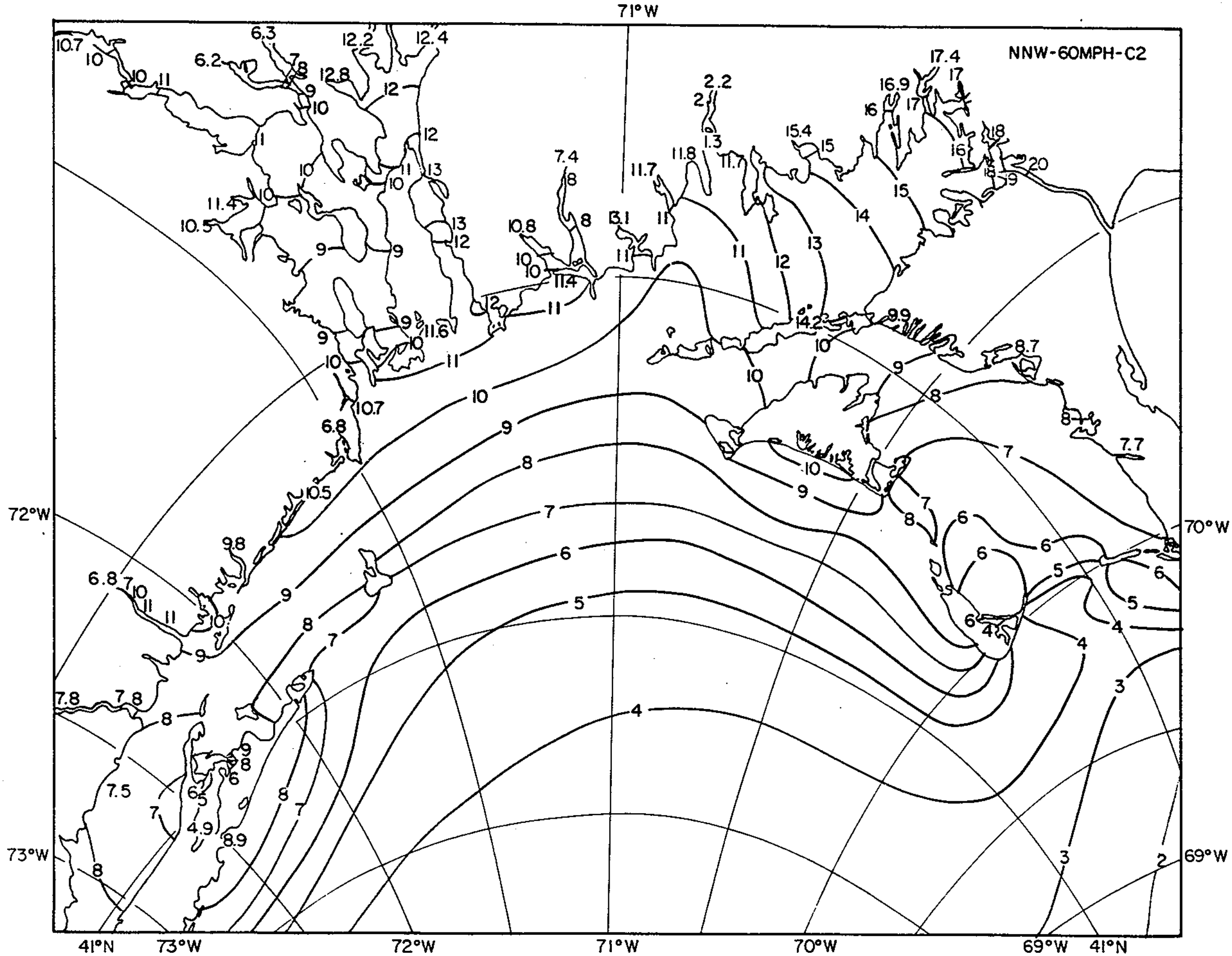
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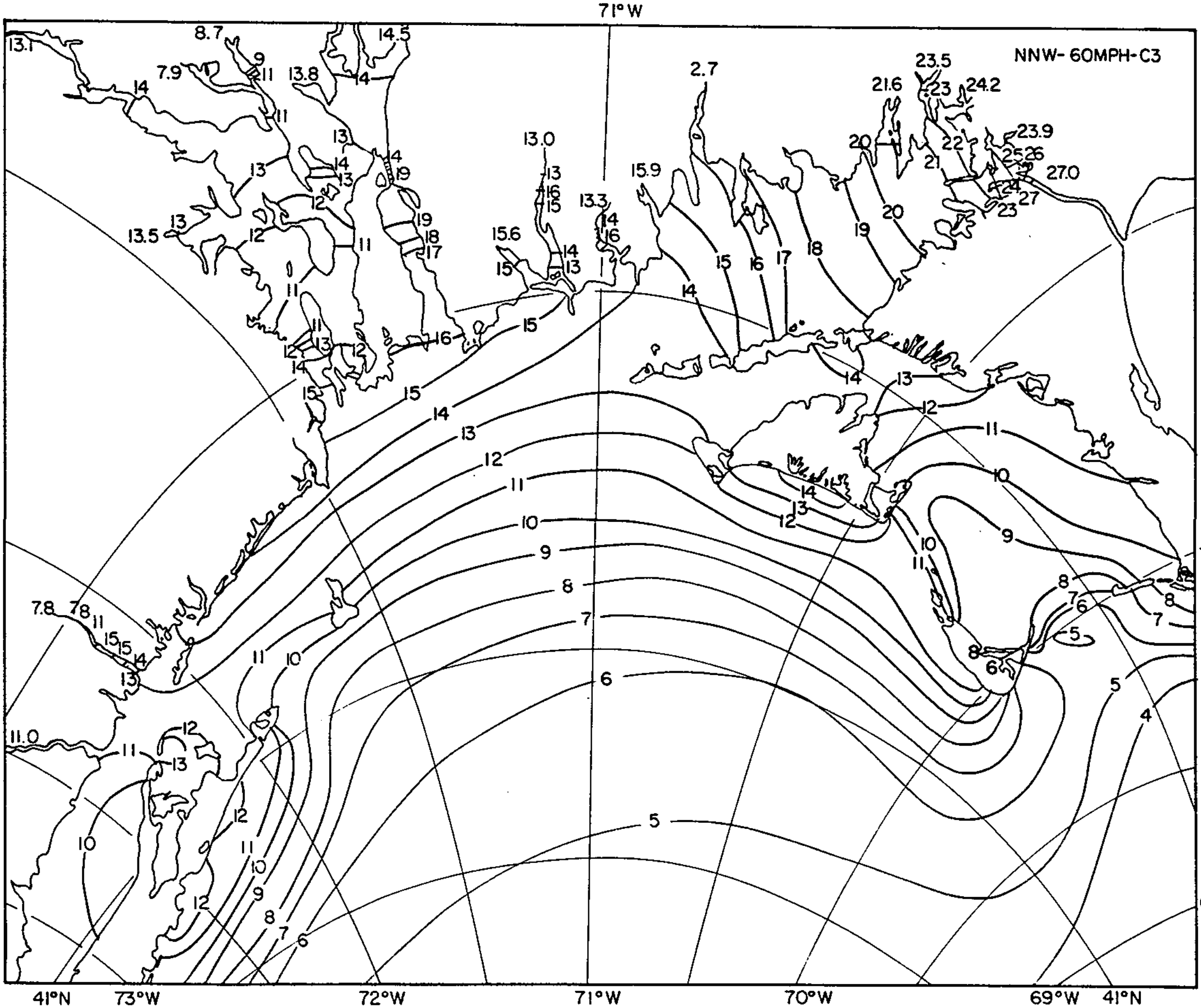
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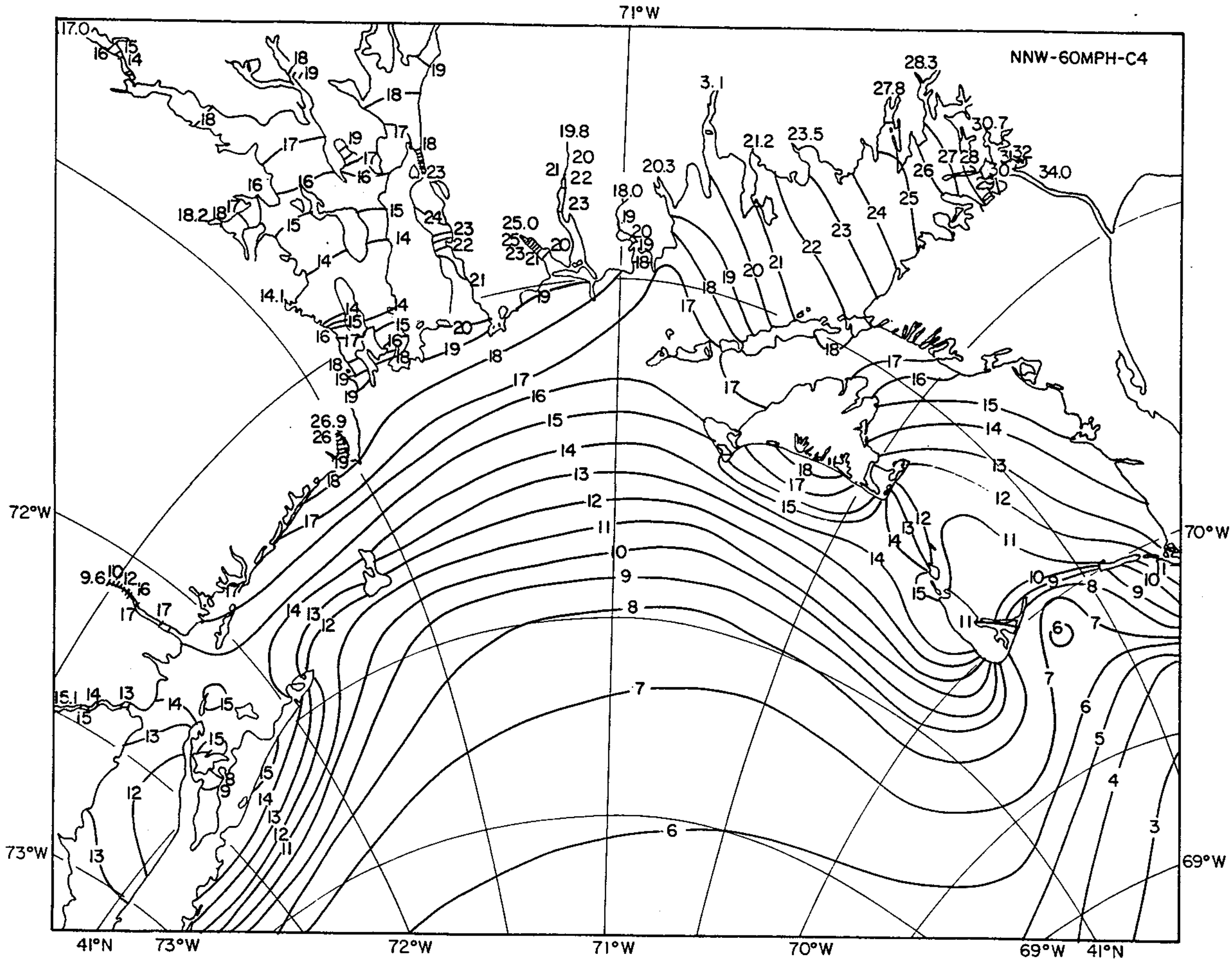
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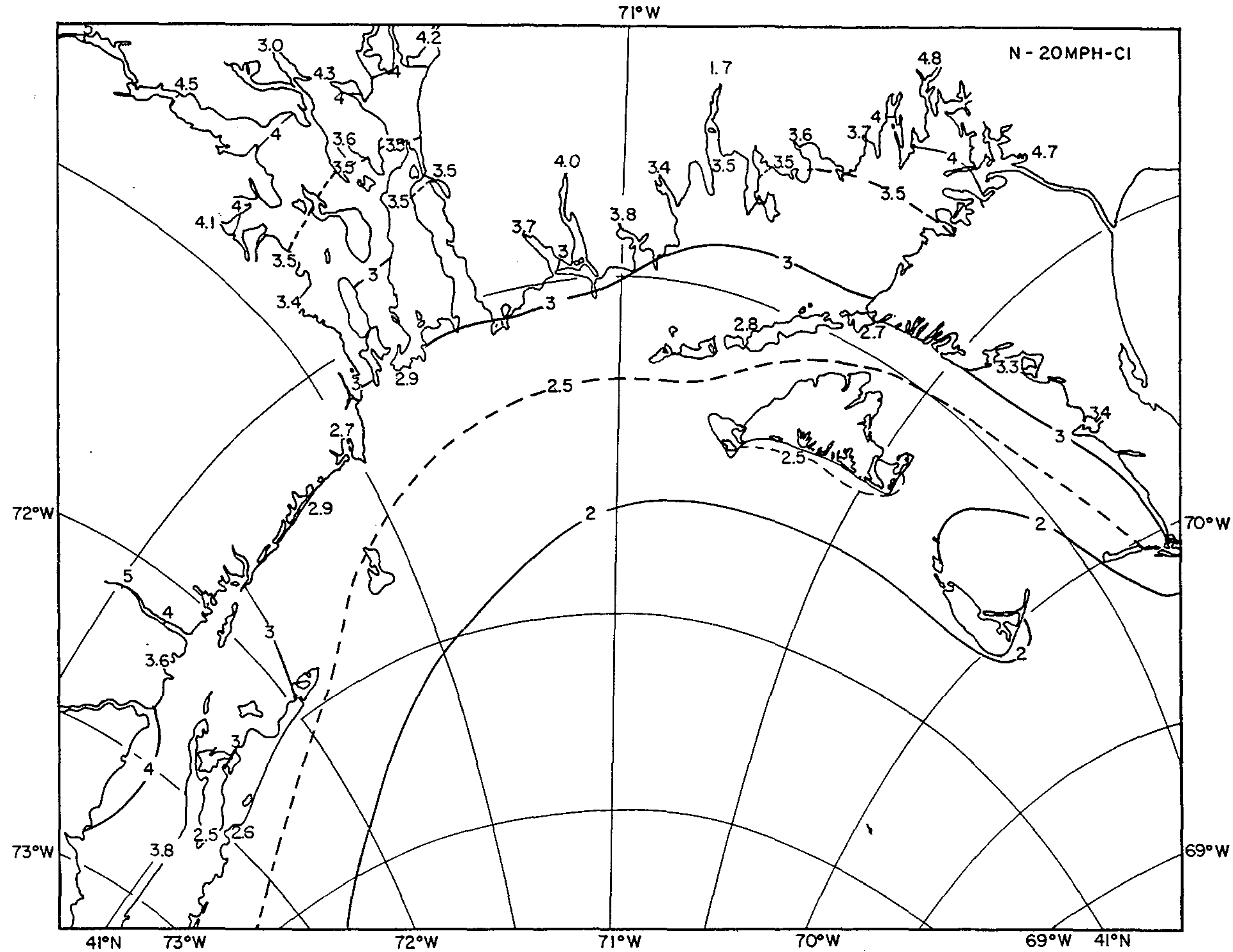
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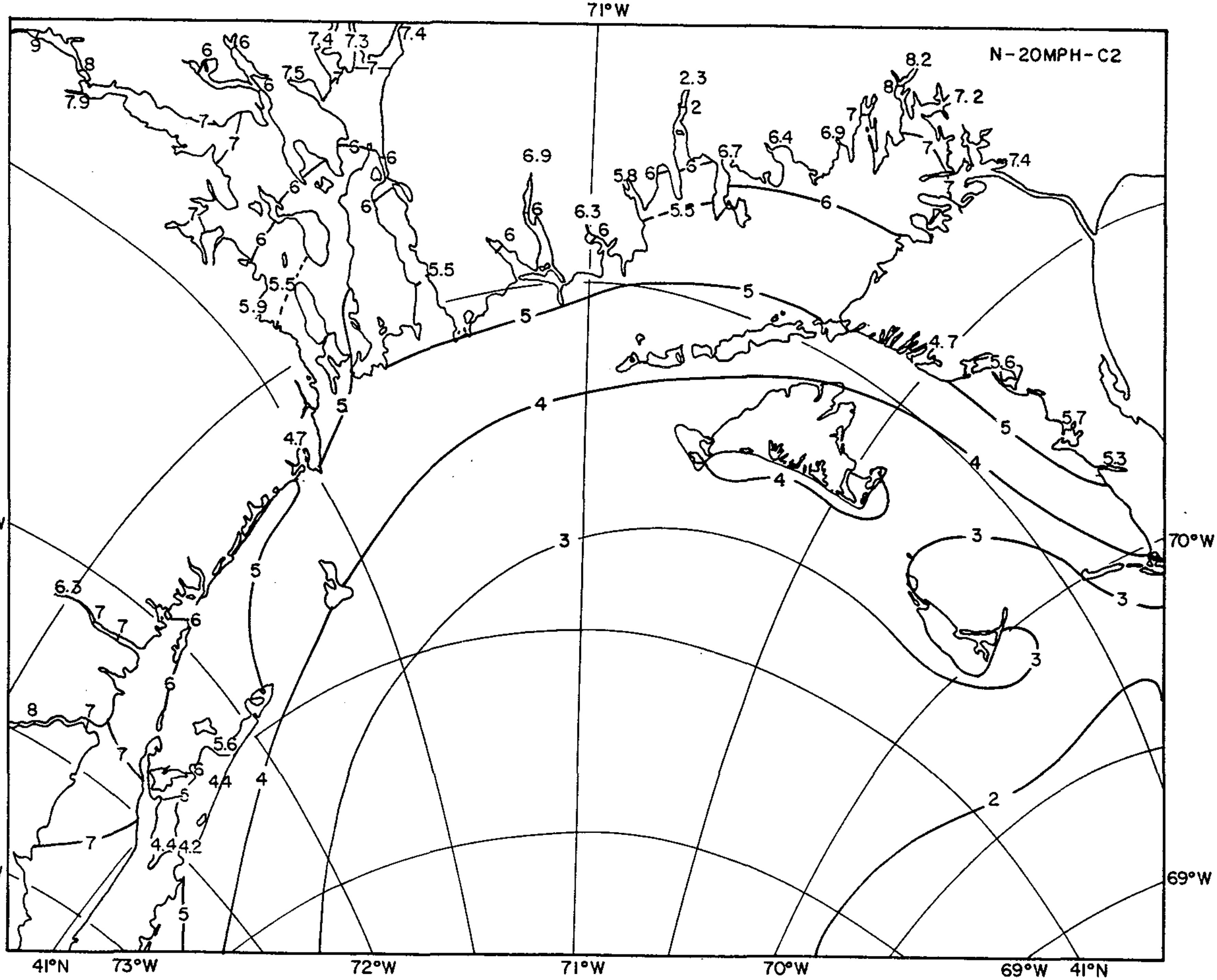
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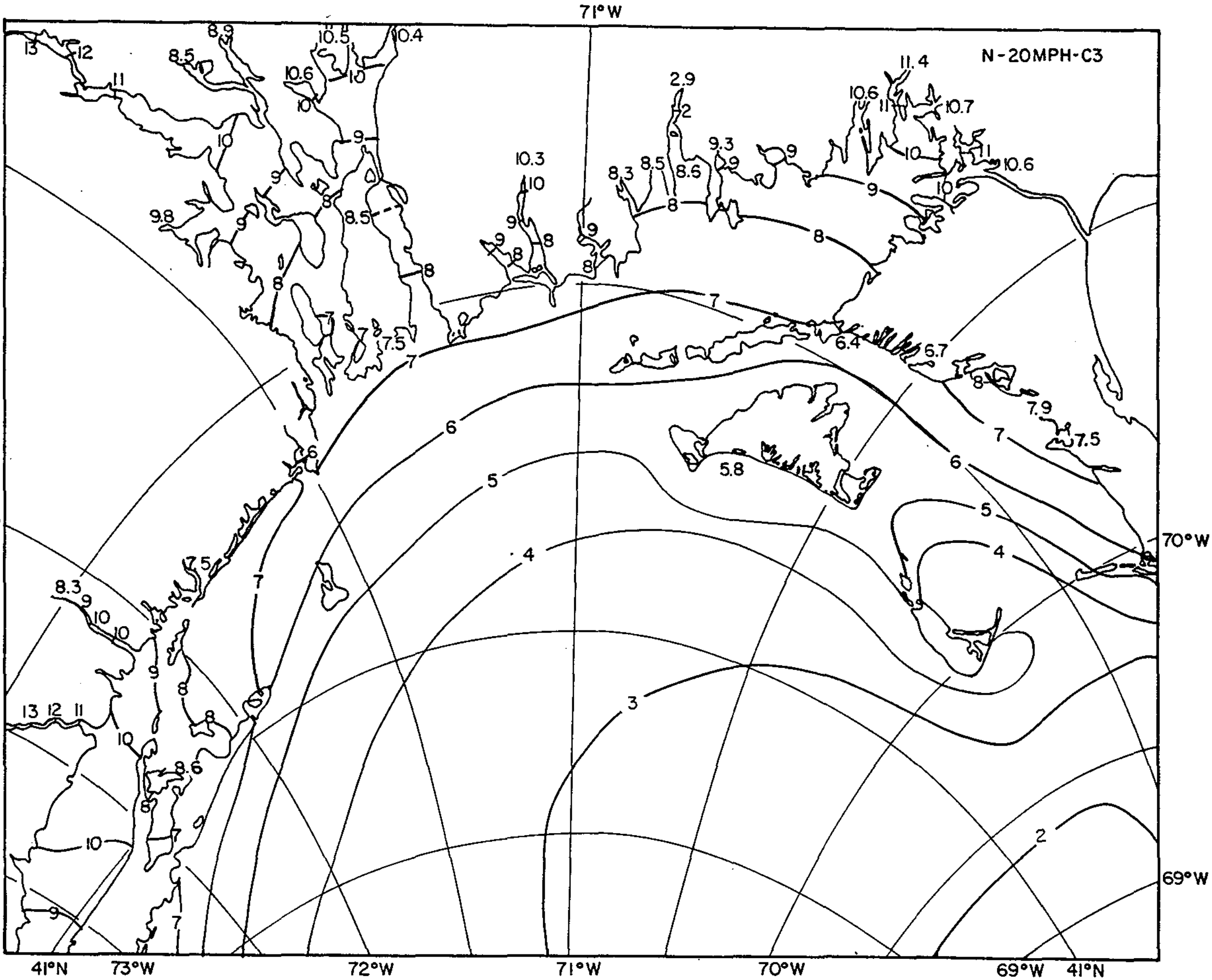

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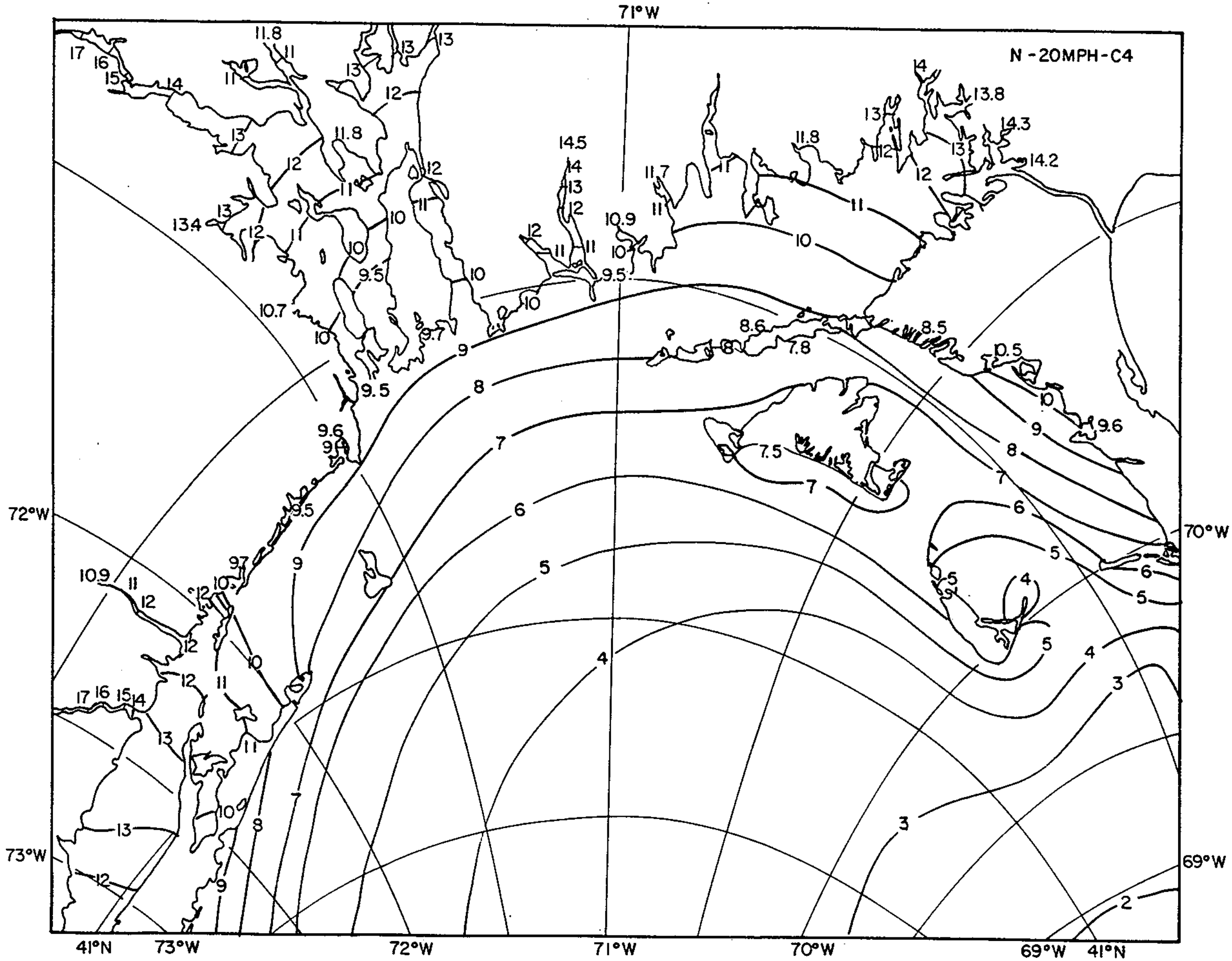
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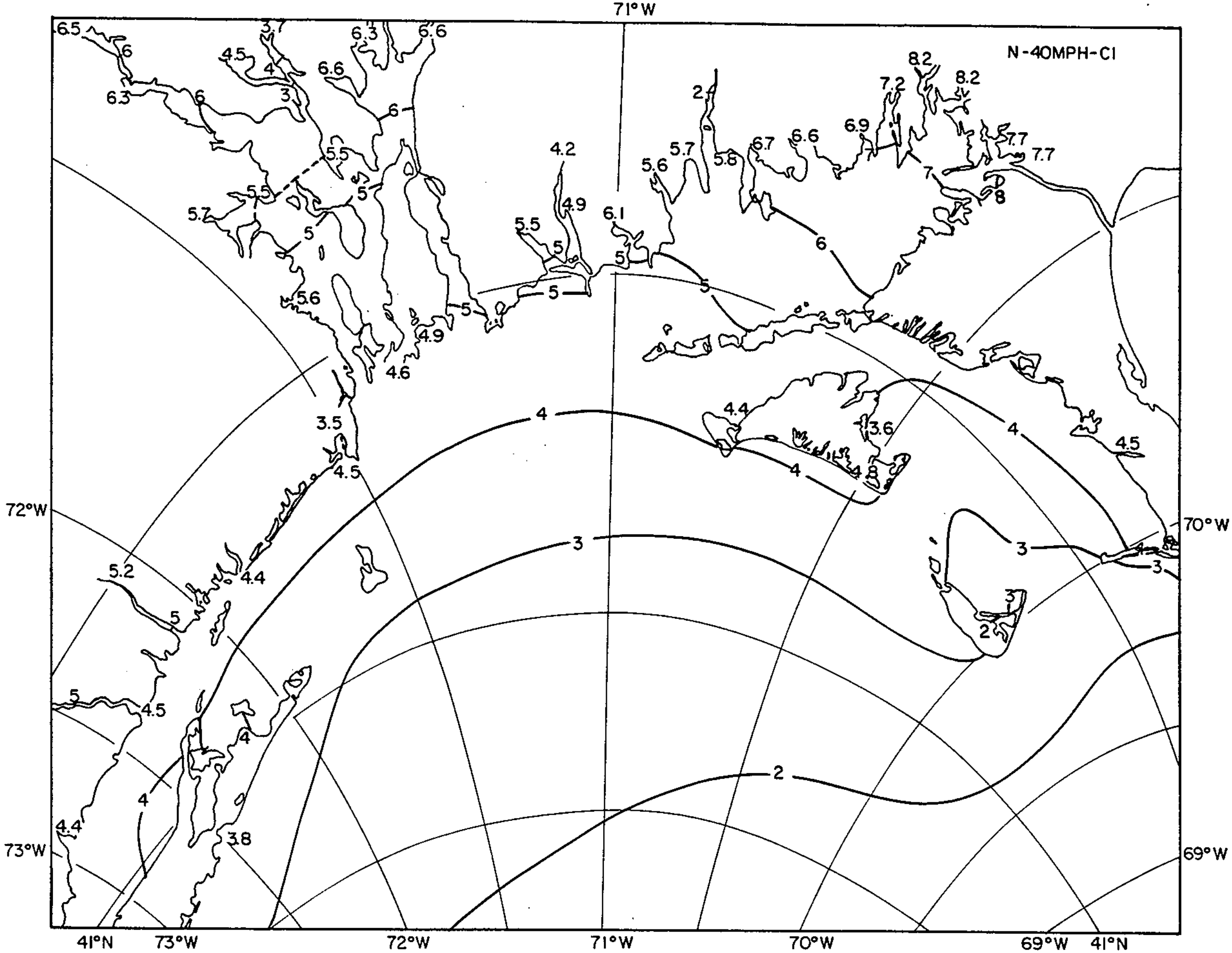
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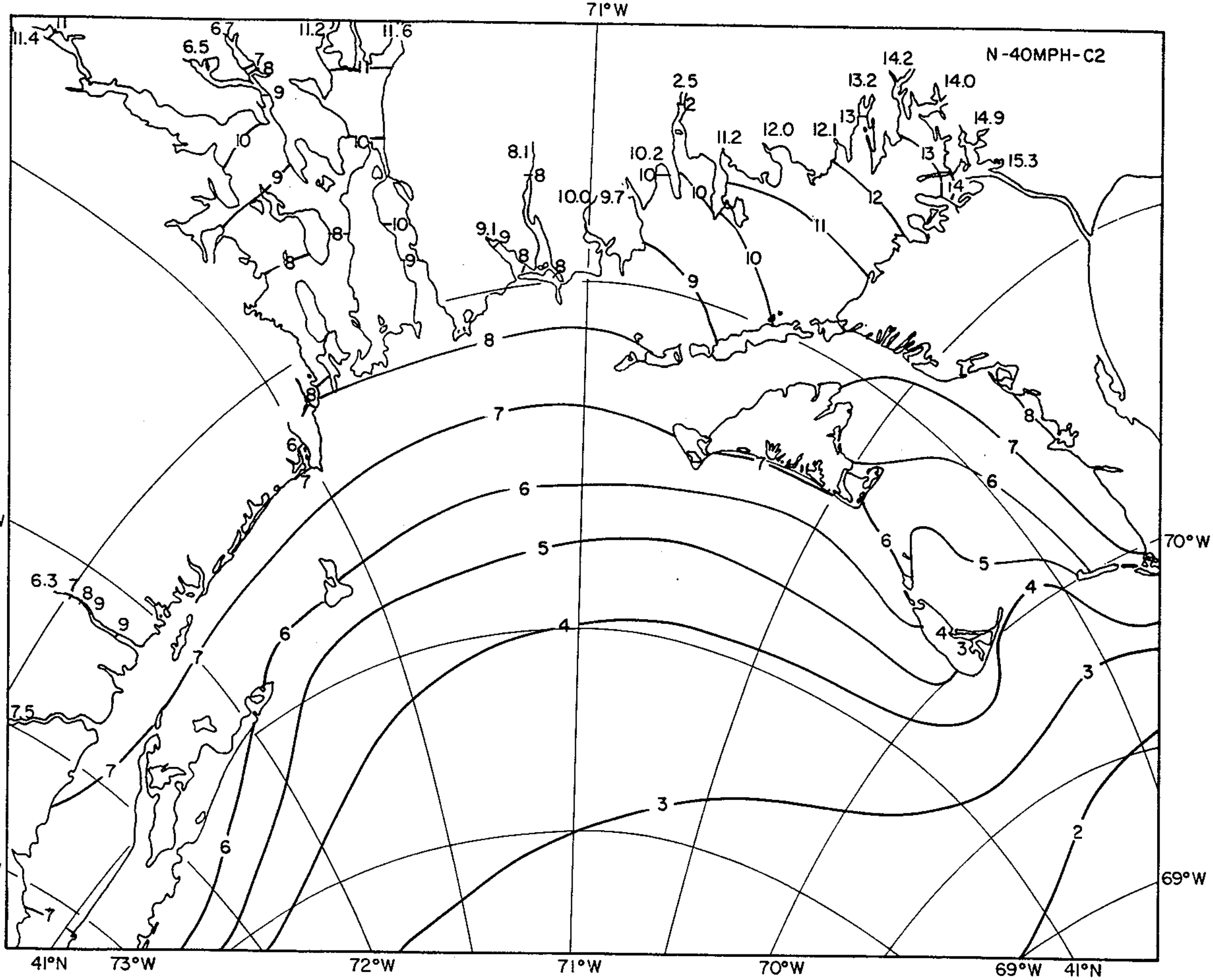
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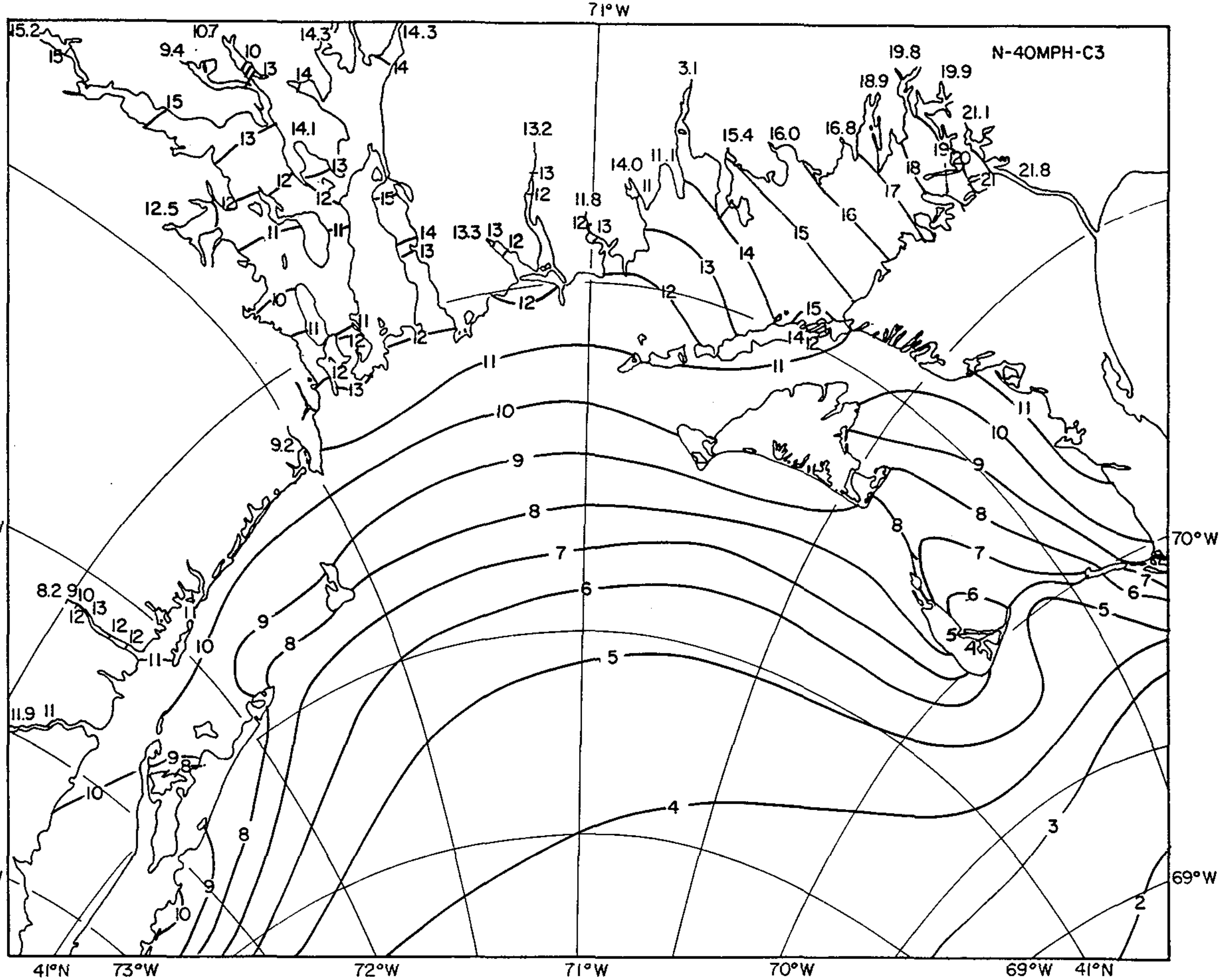
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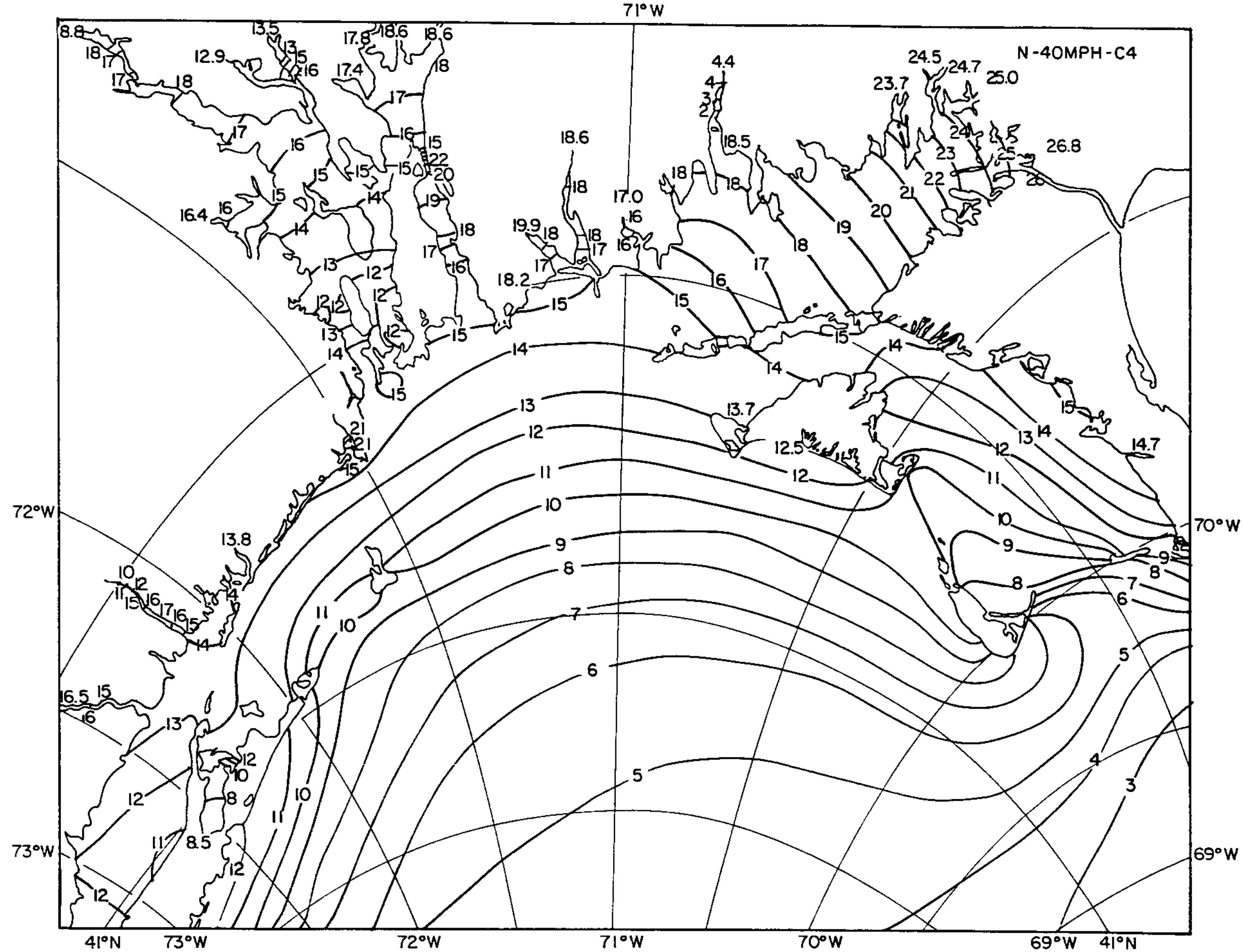
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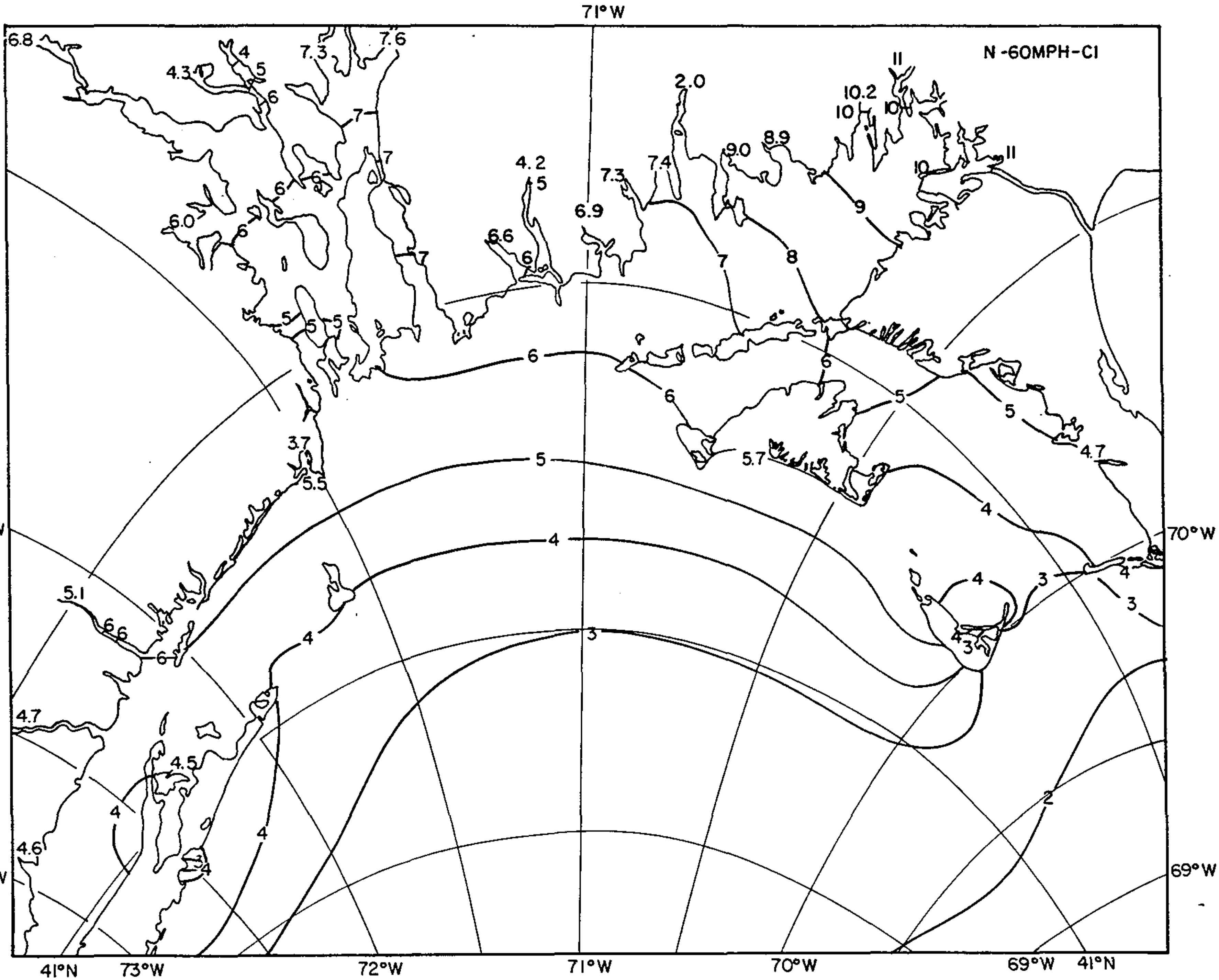
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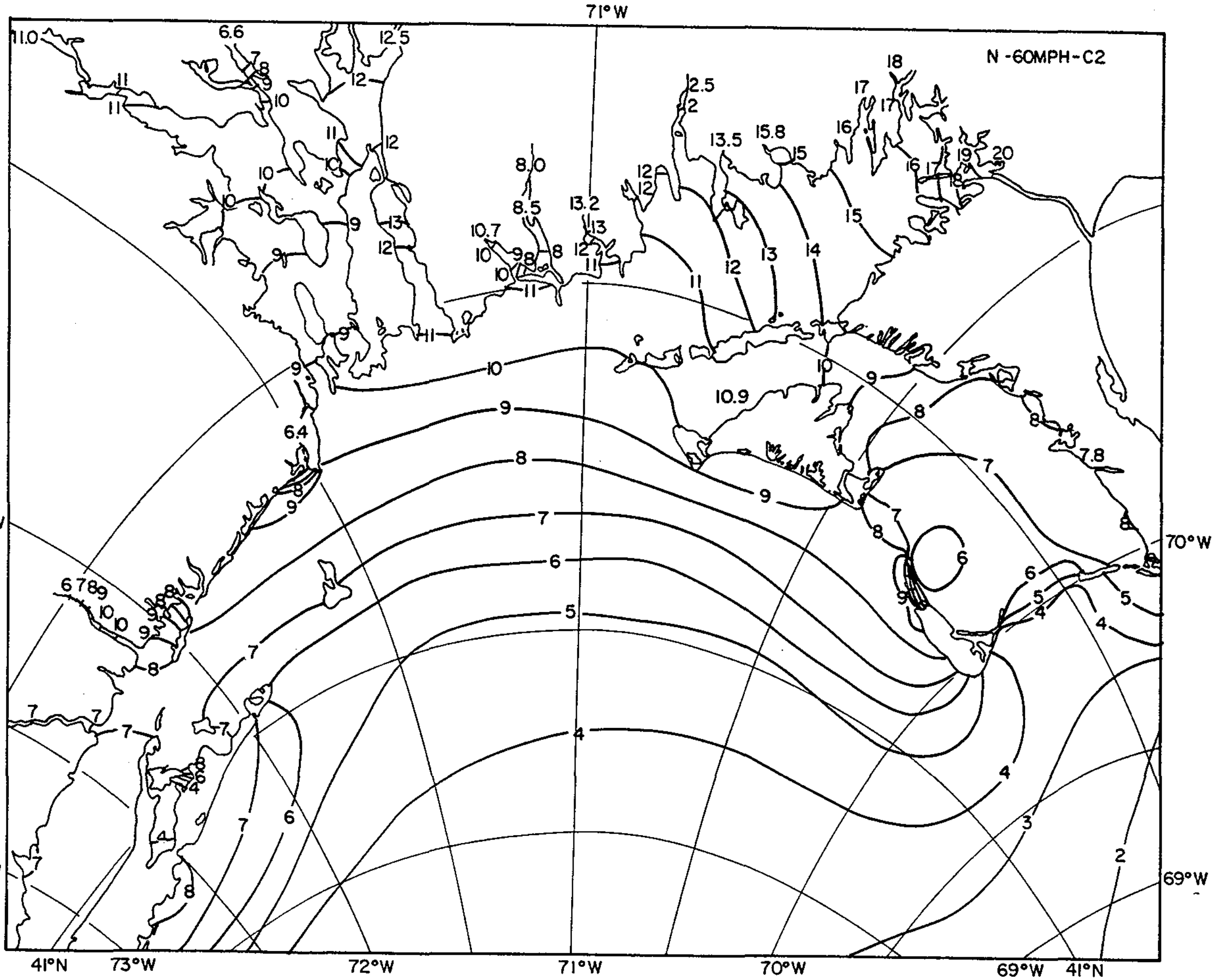
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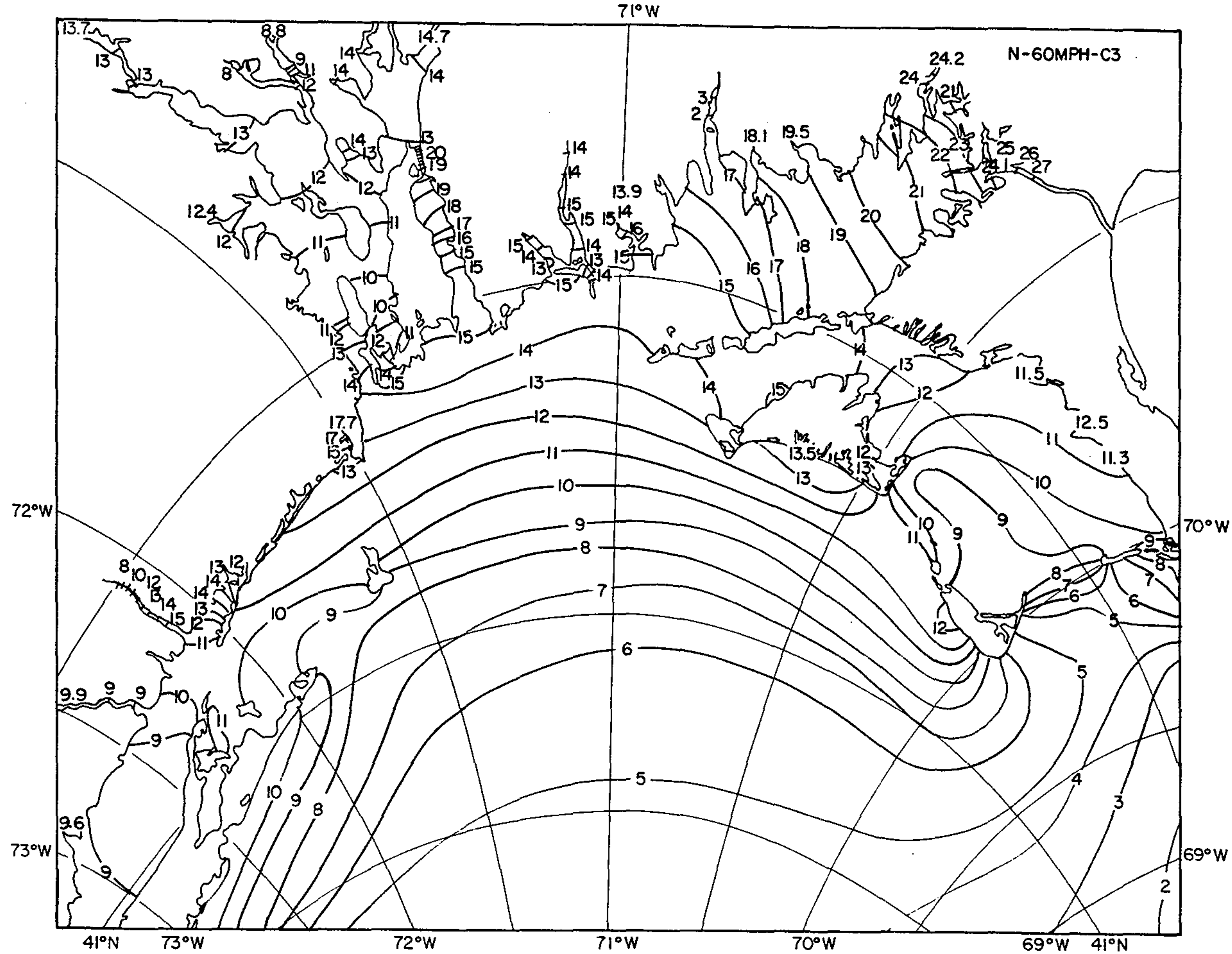
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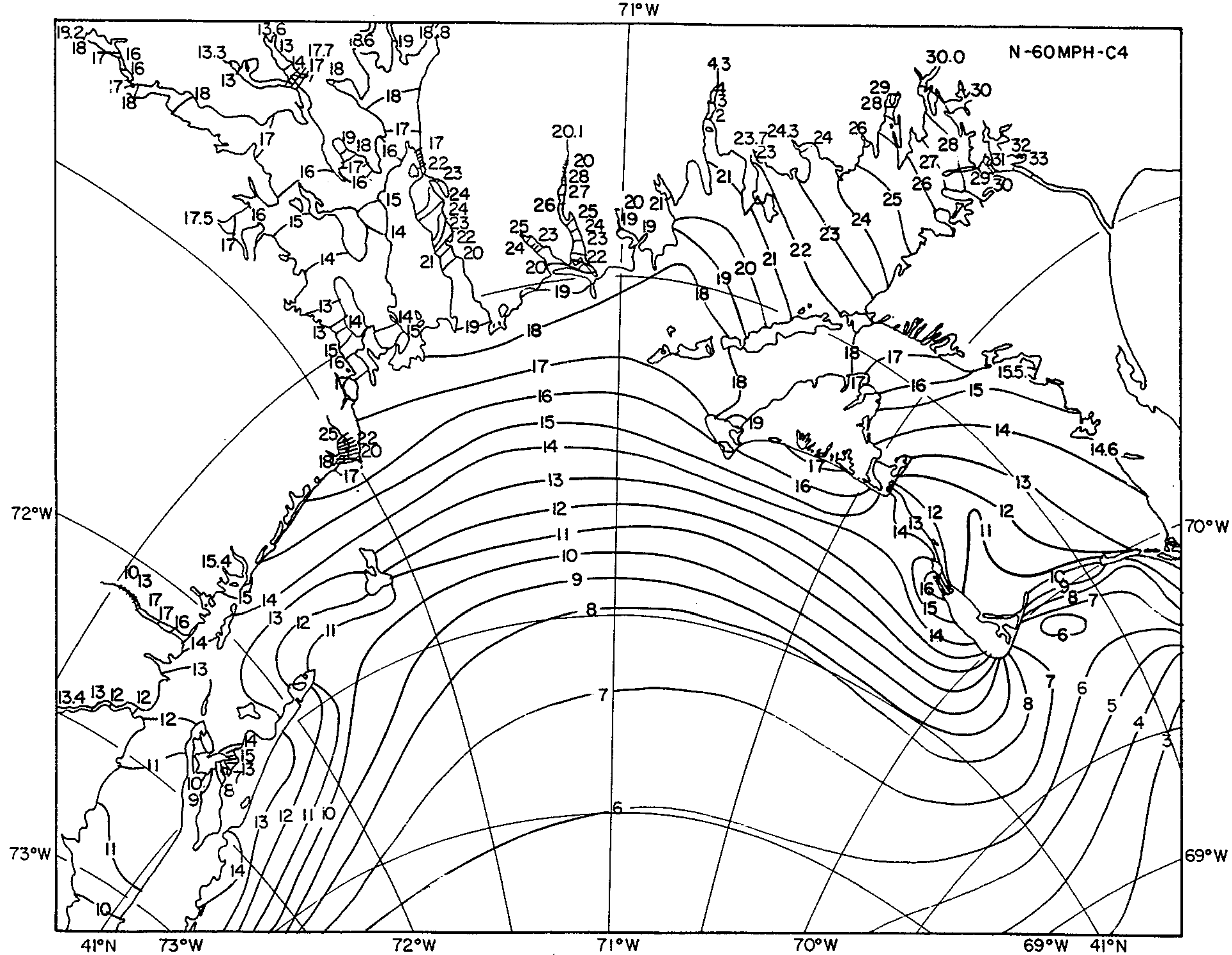
41°N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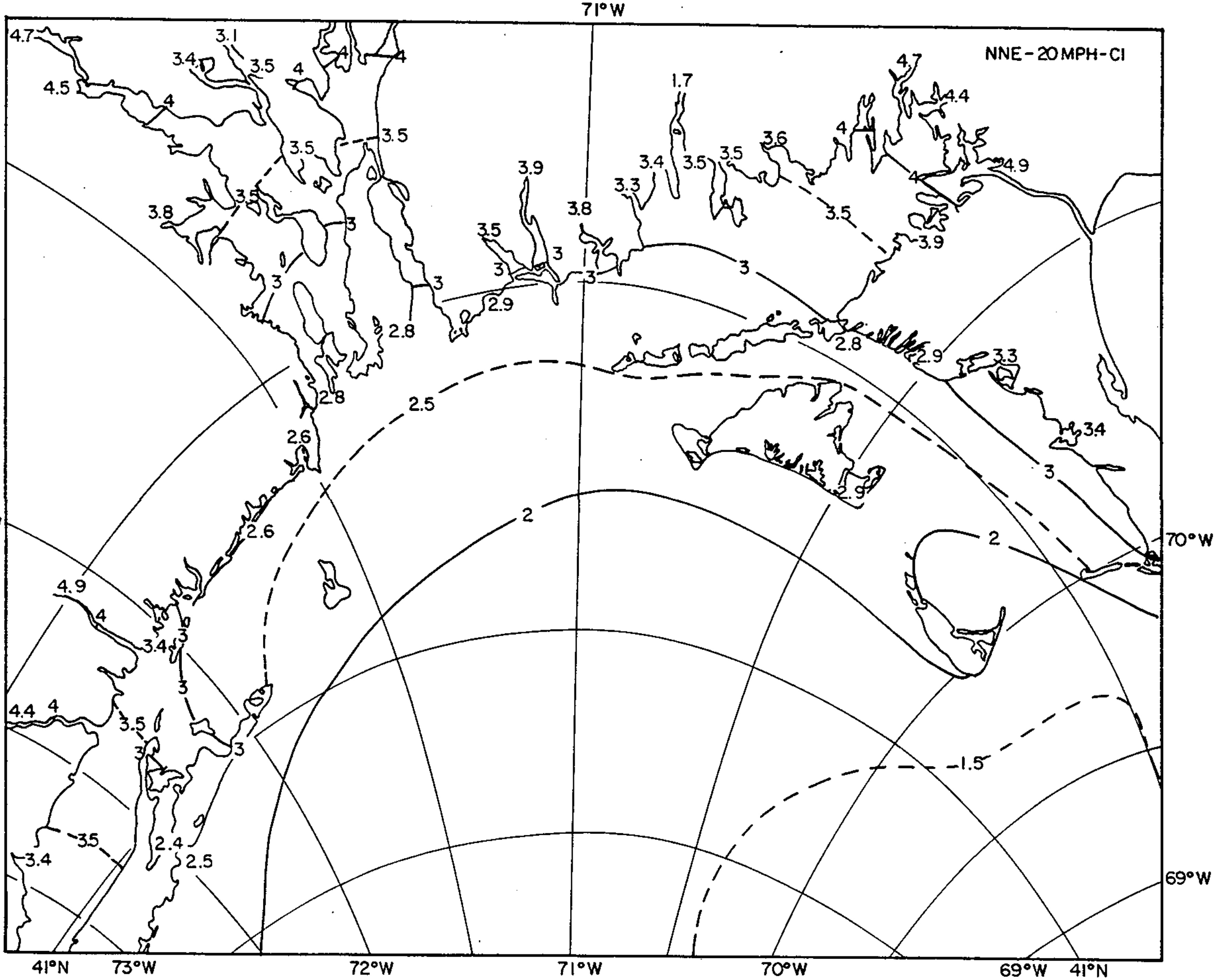
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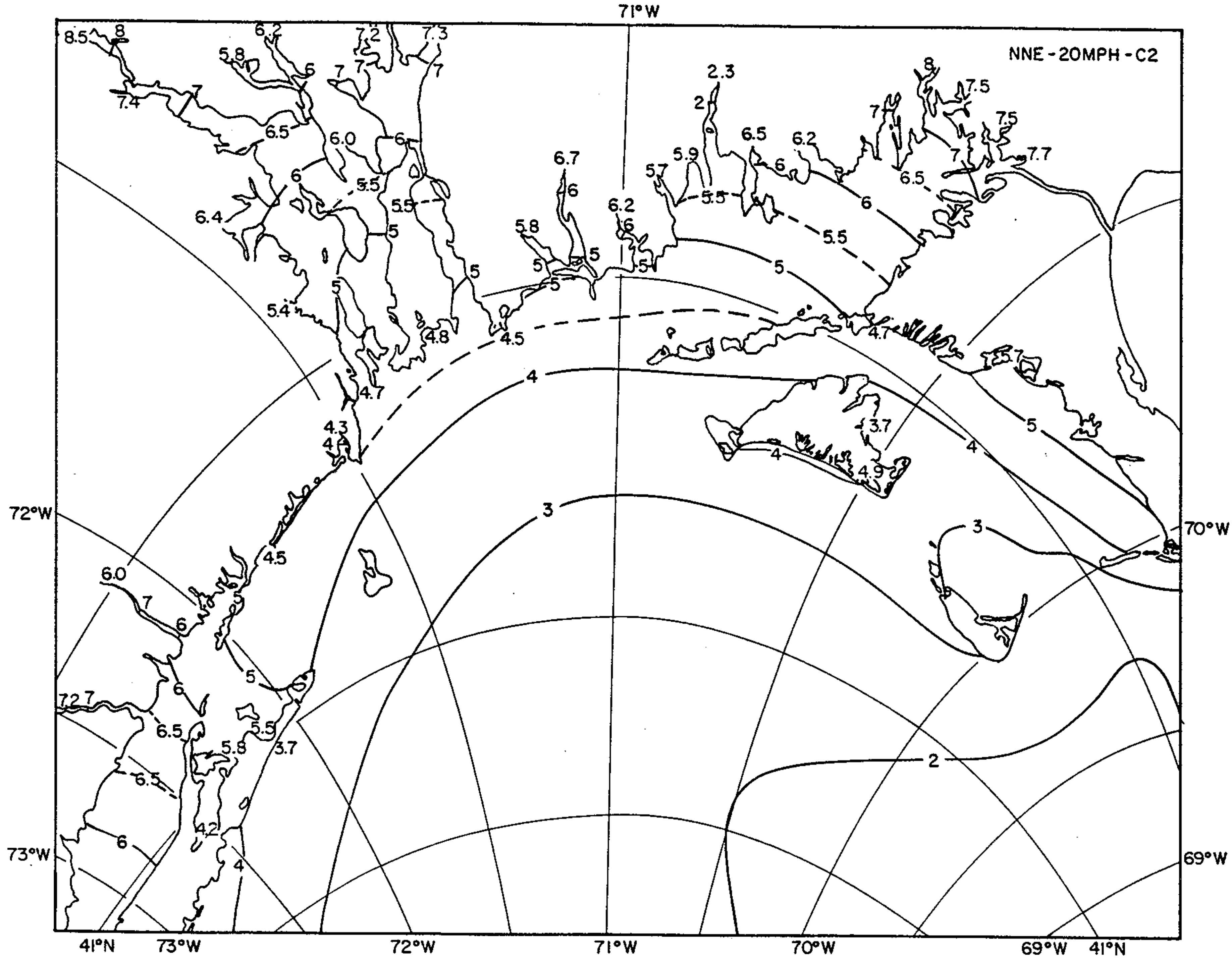
A-33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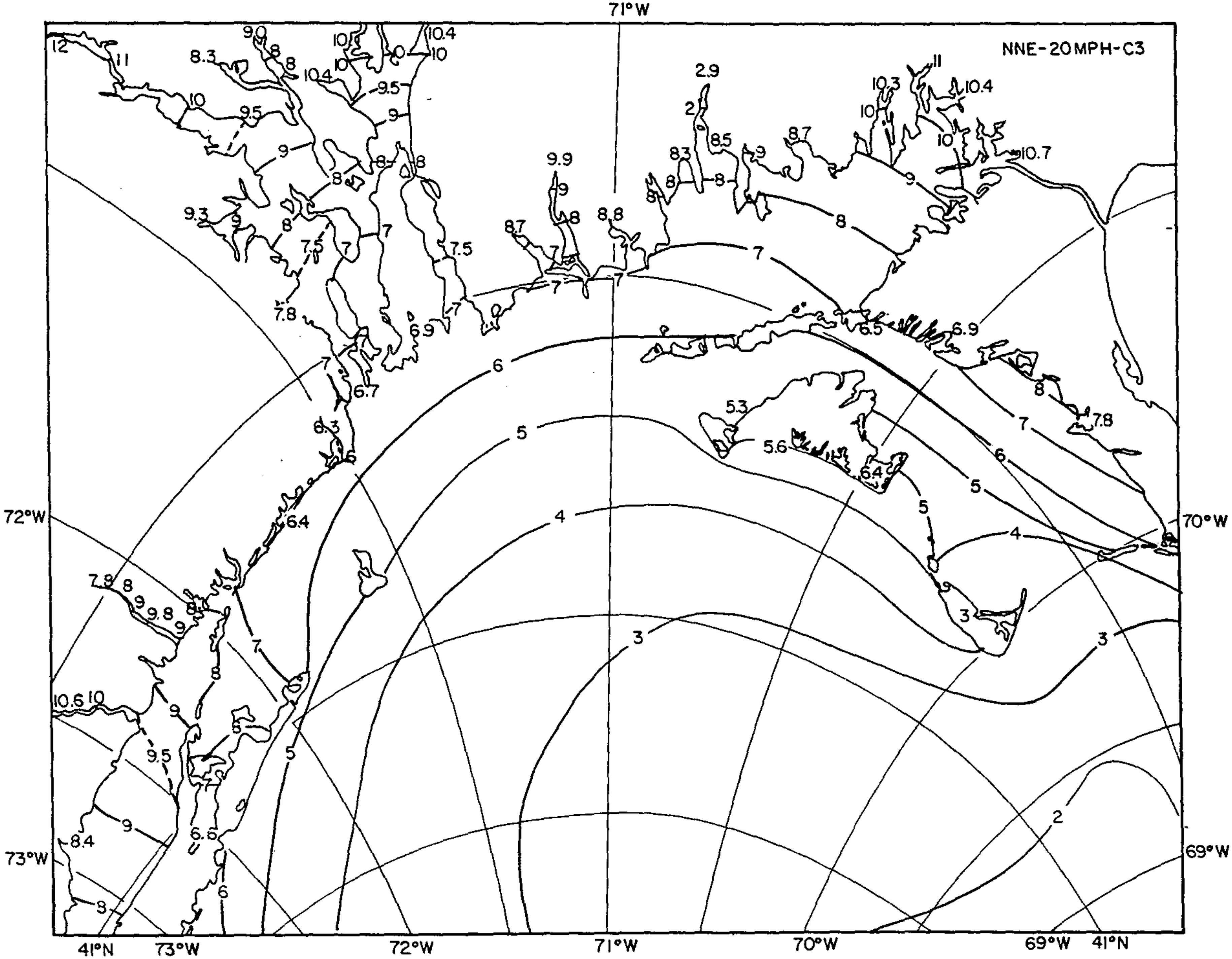
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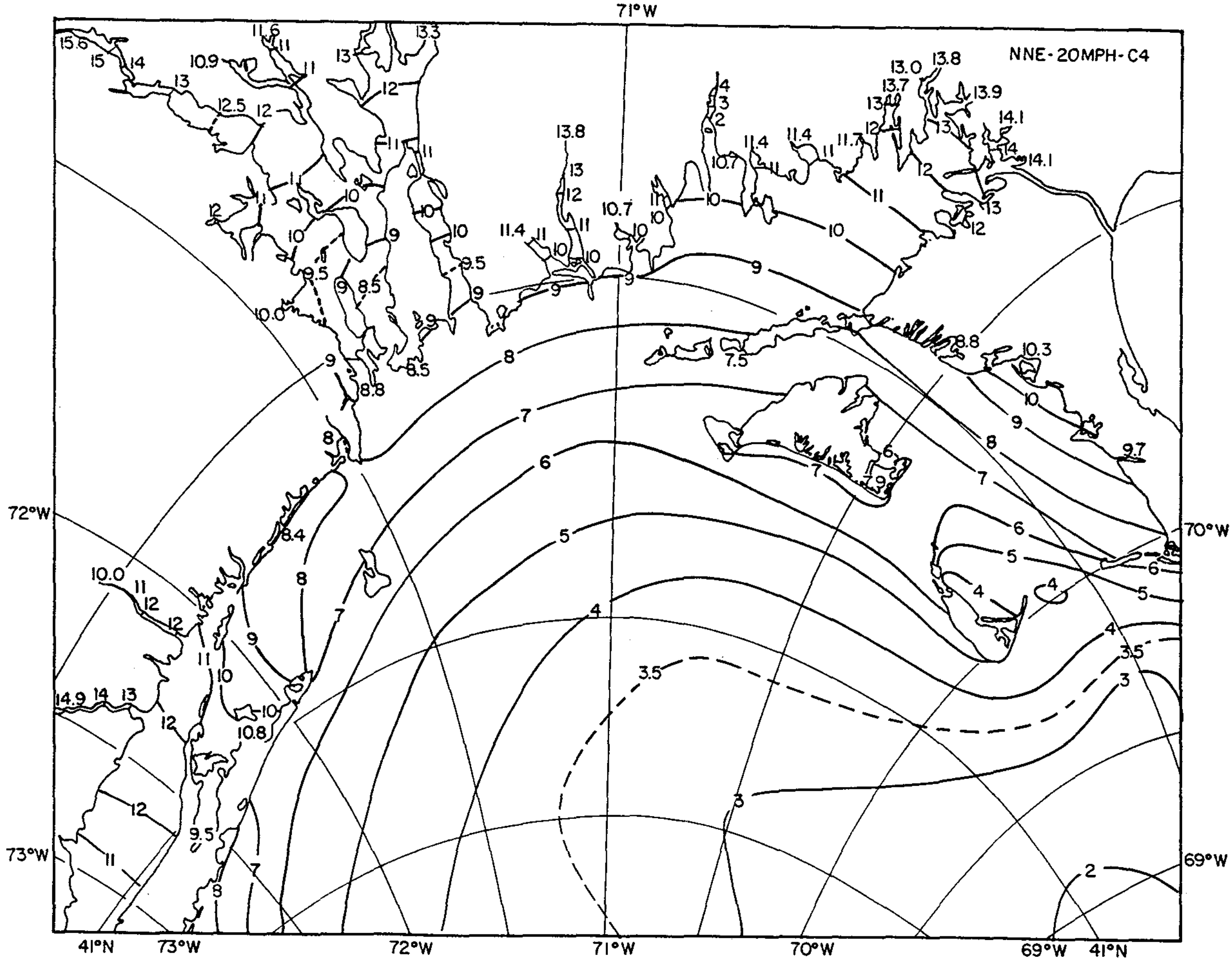
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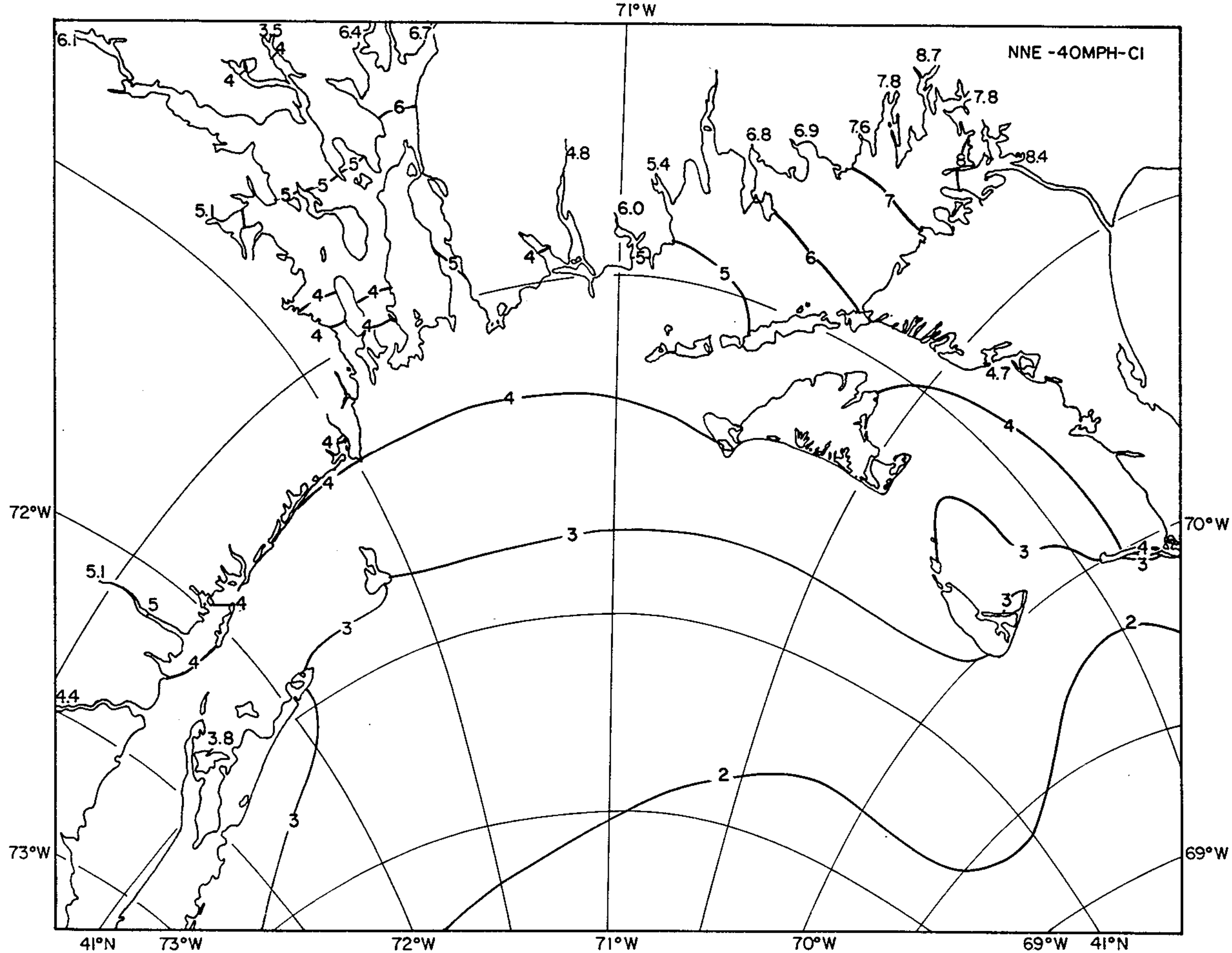
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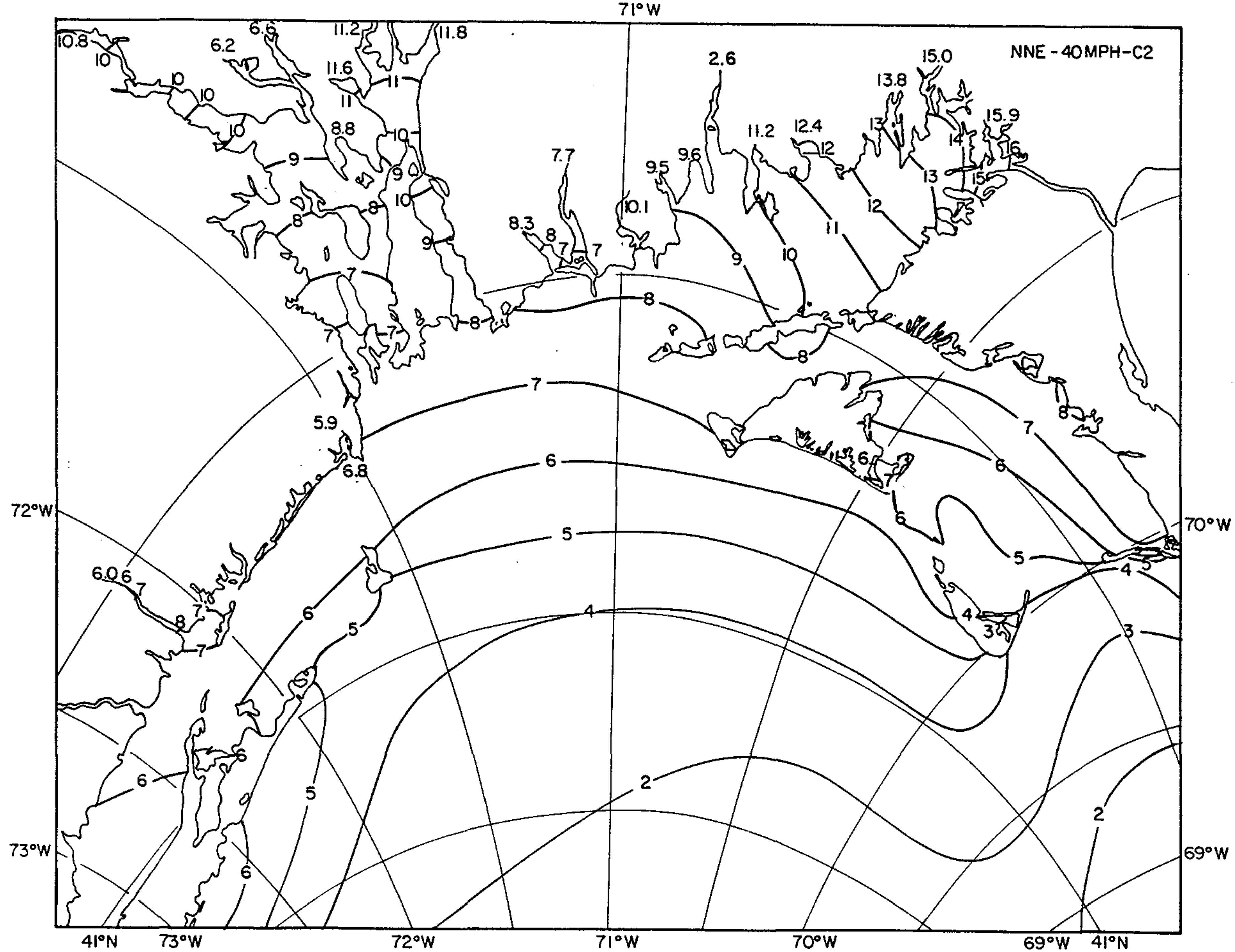
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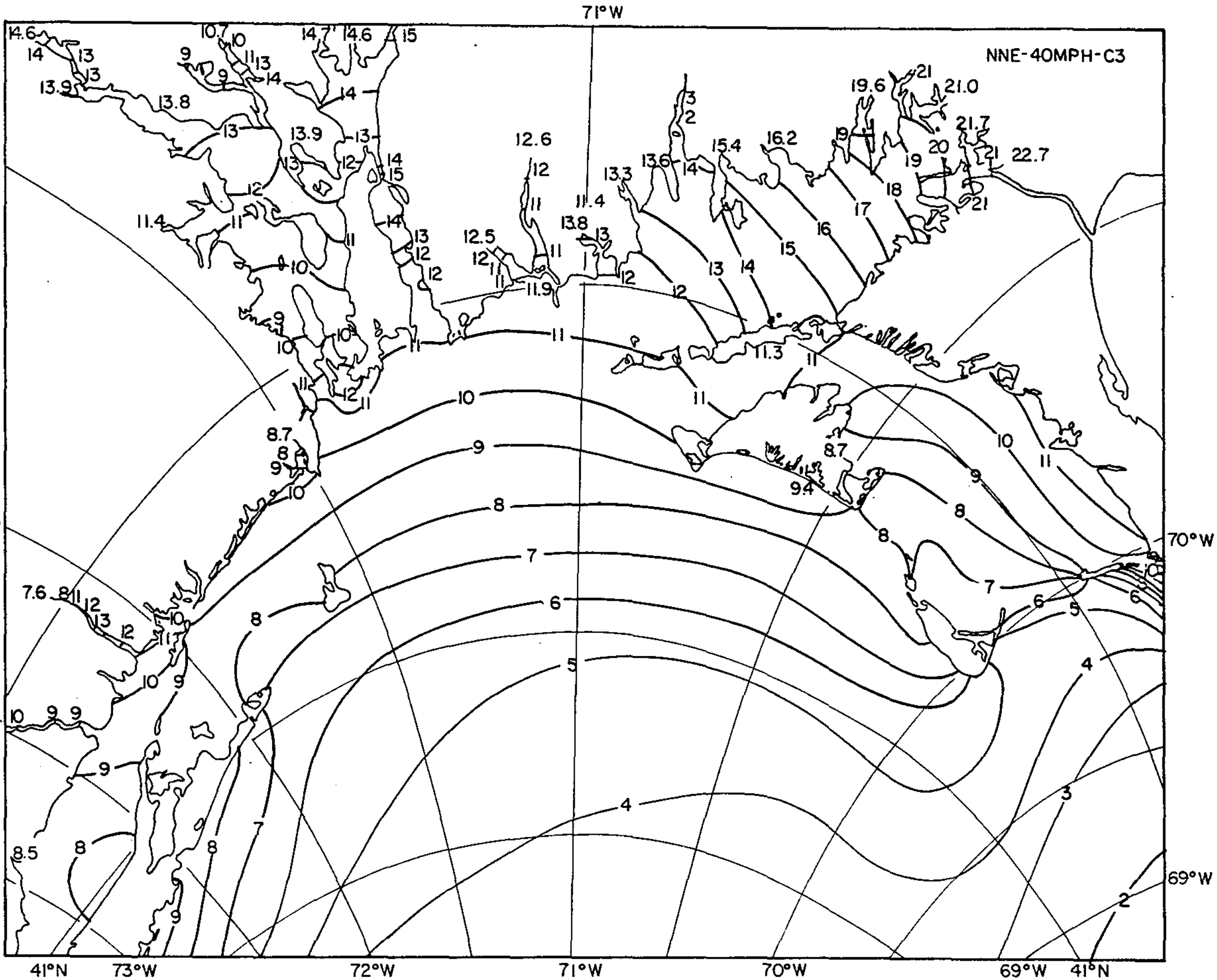
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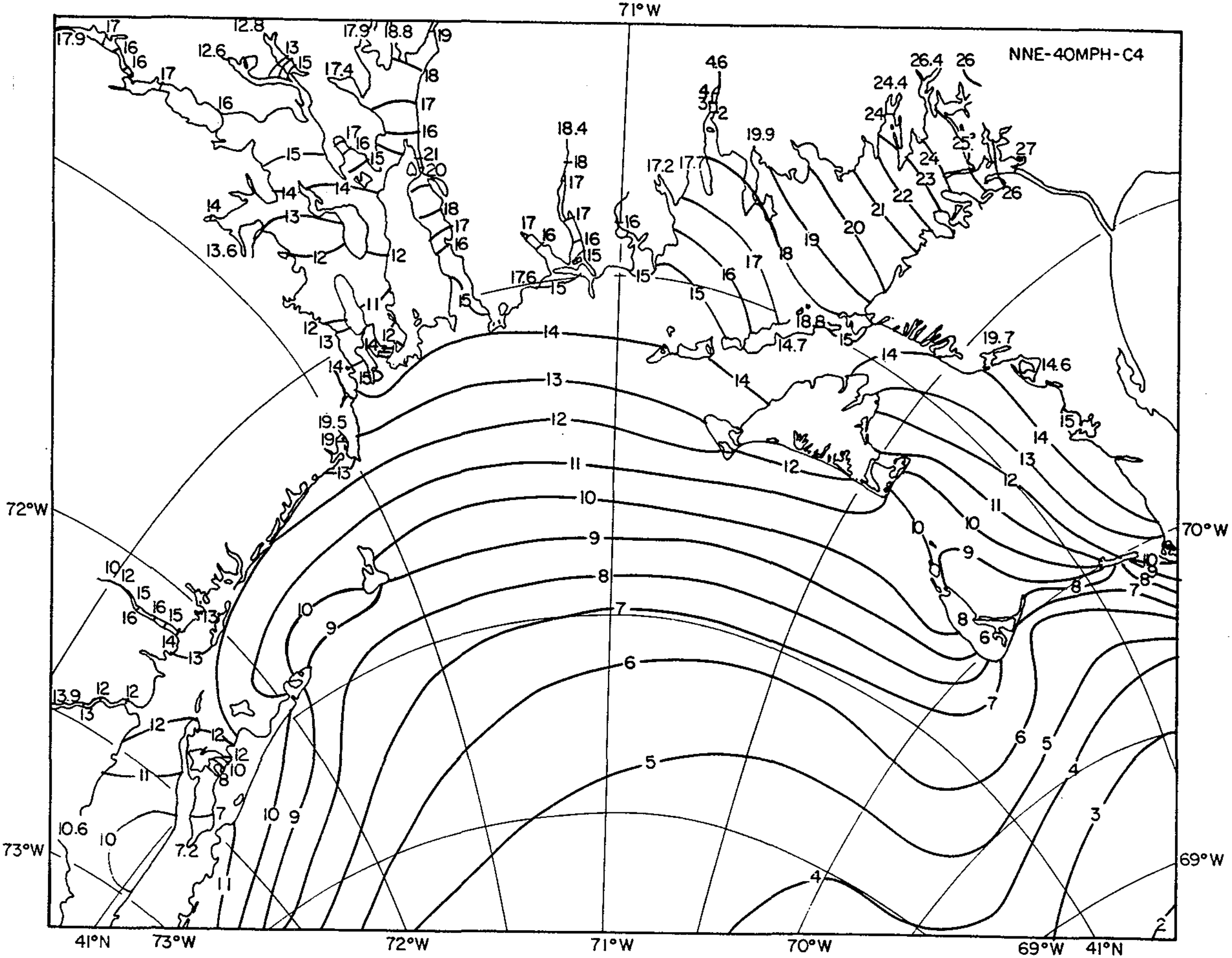
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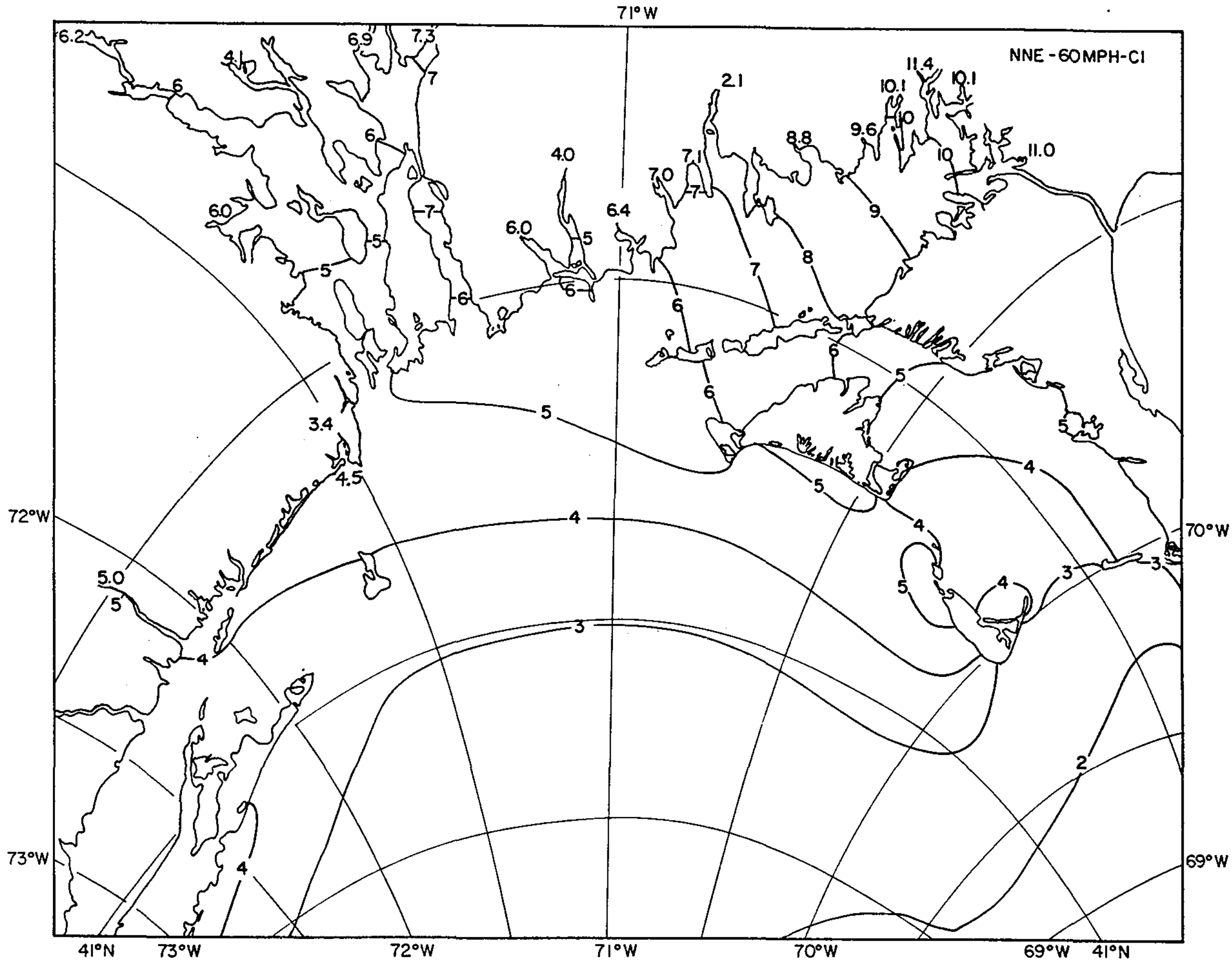
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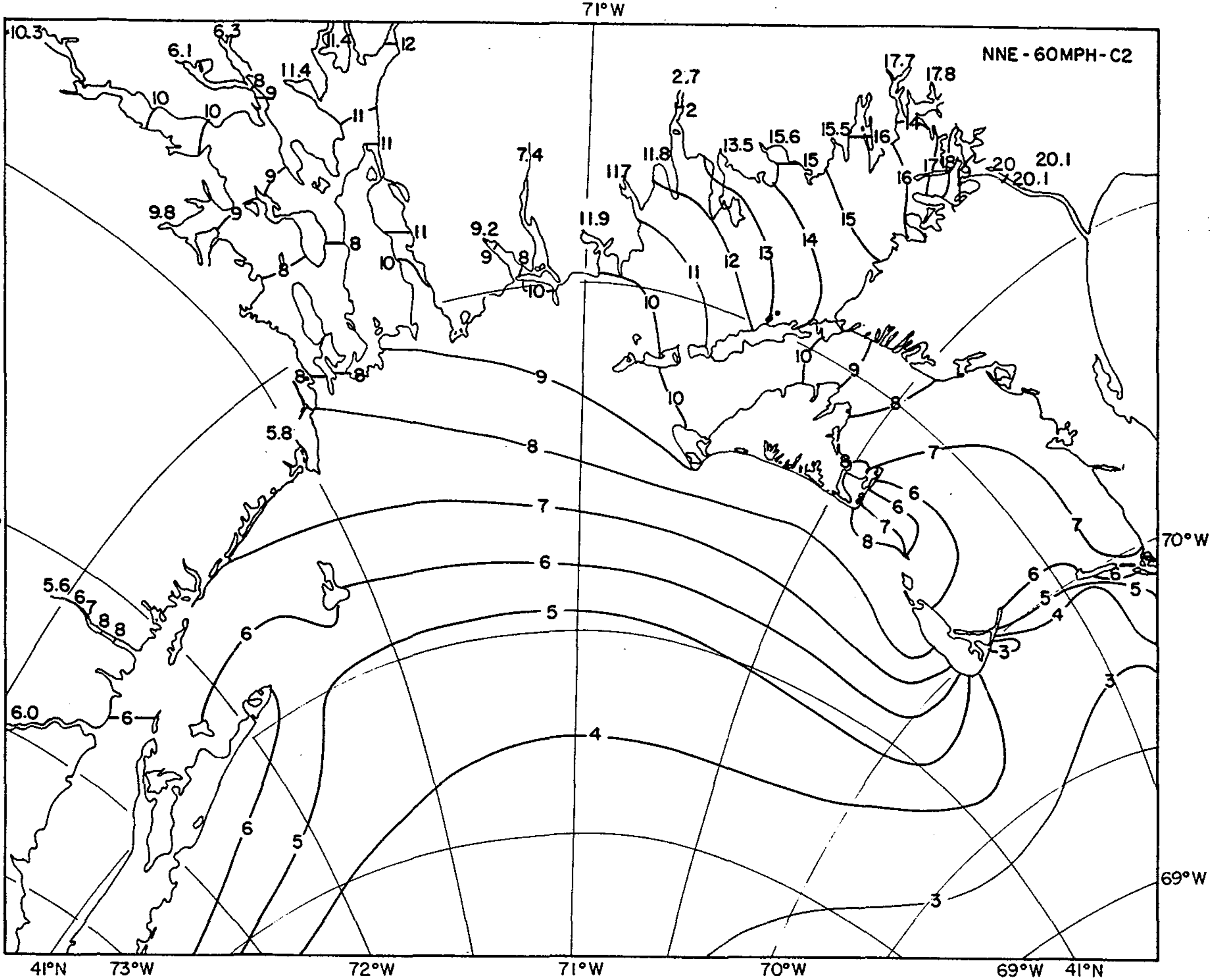
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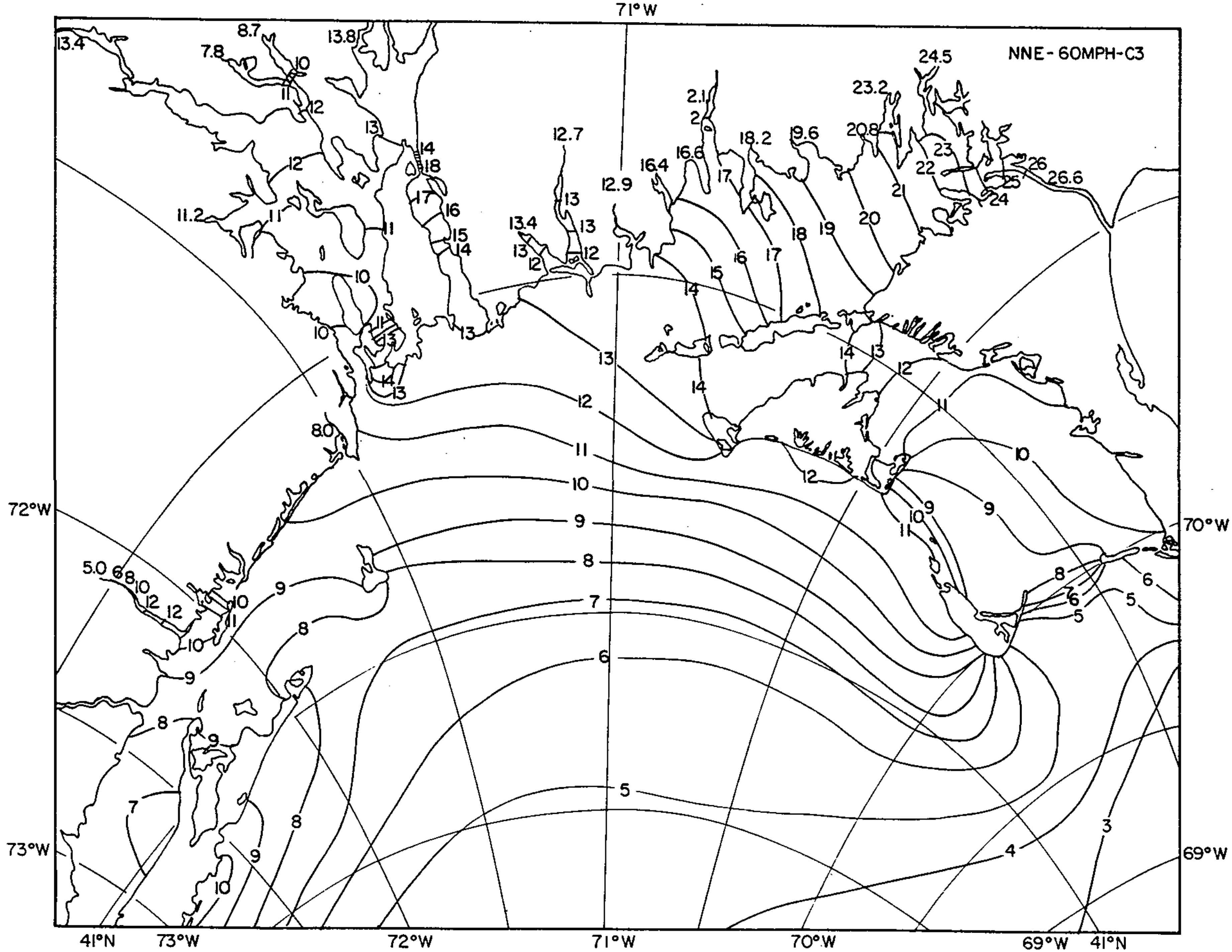
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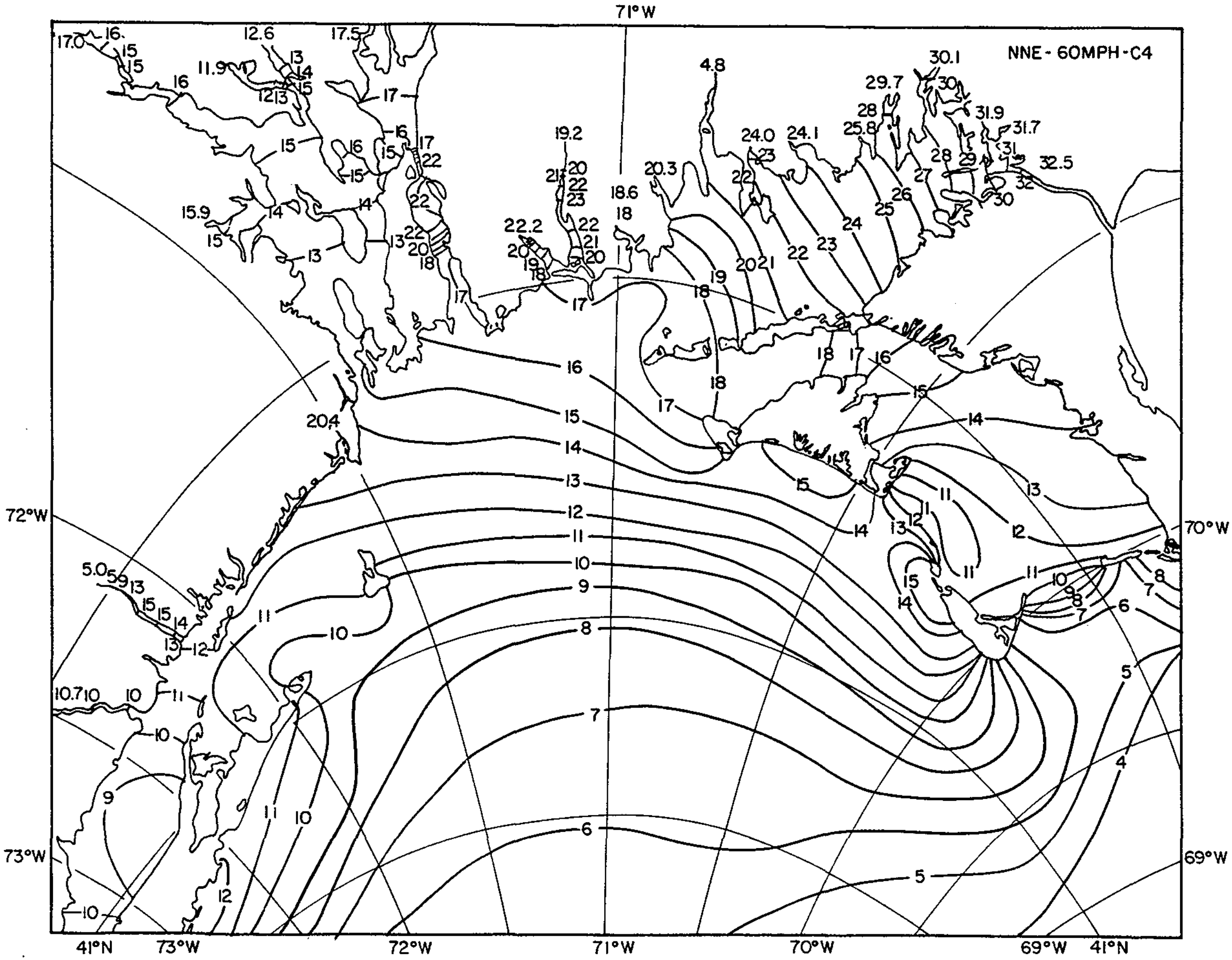
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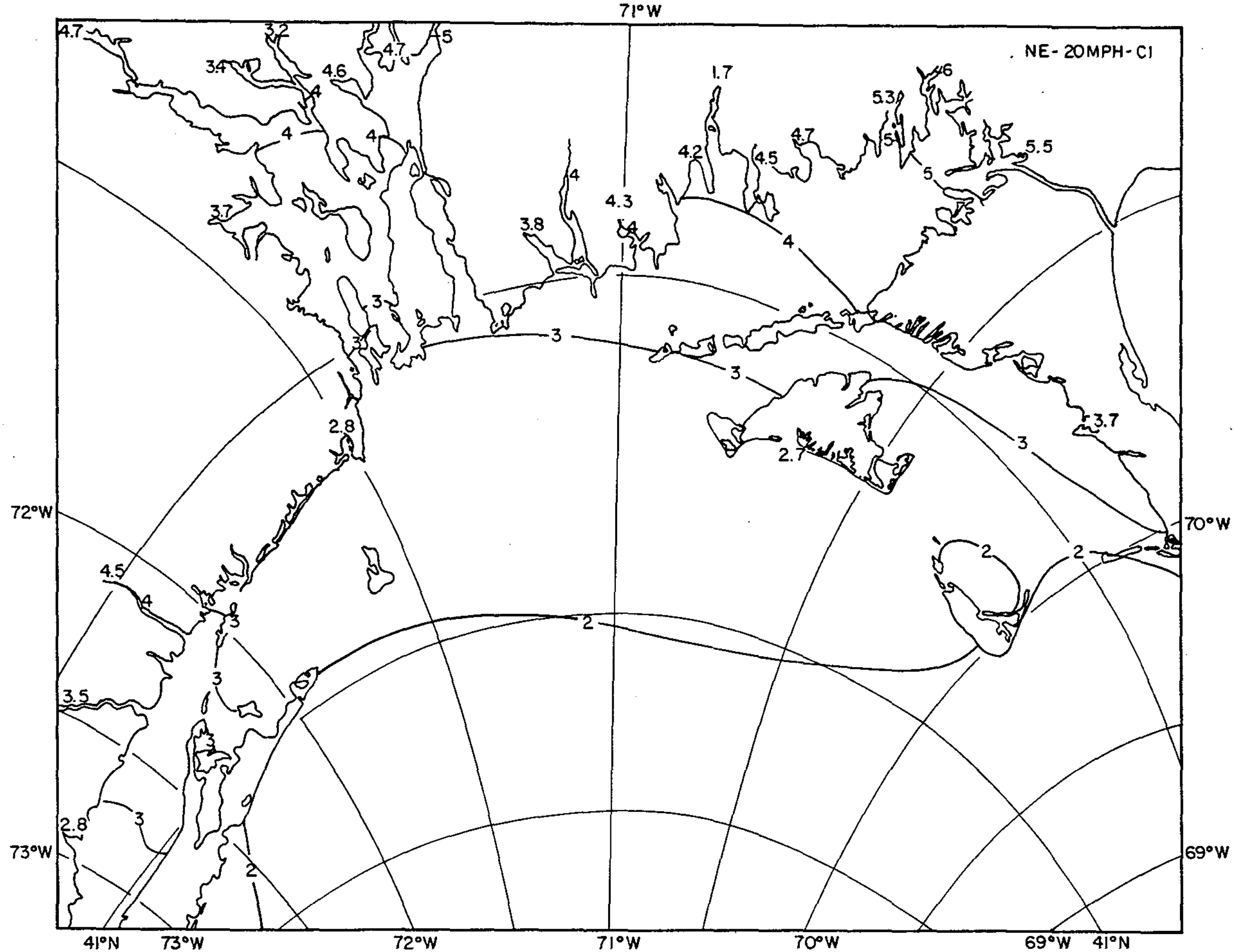
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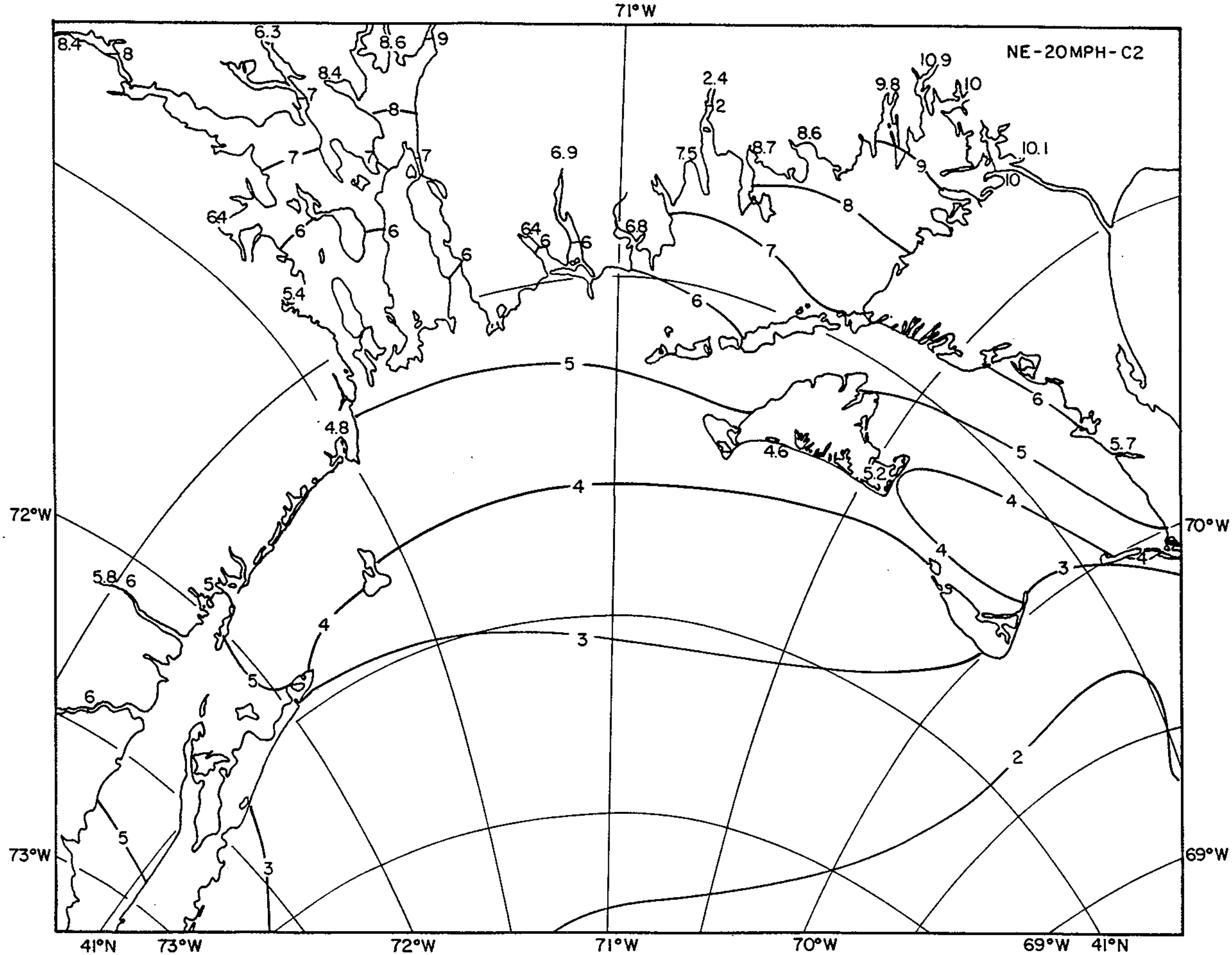

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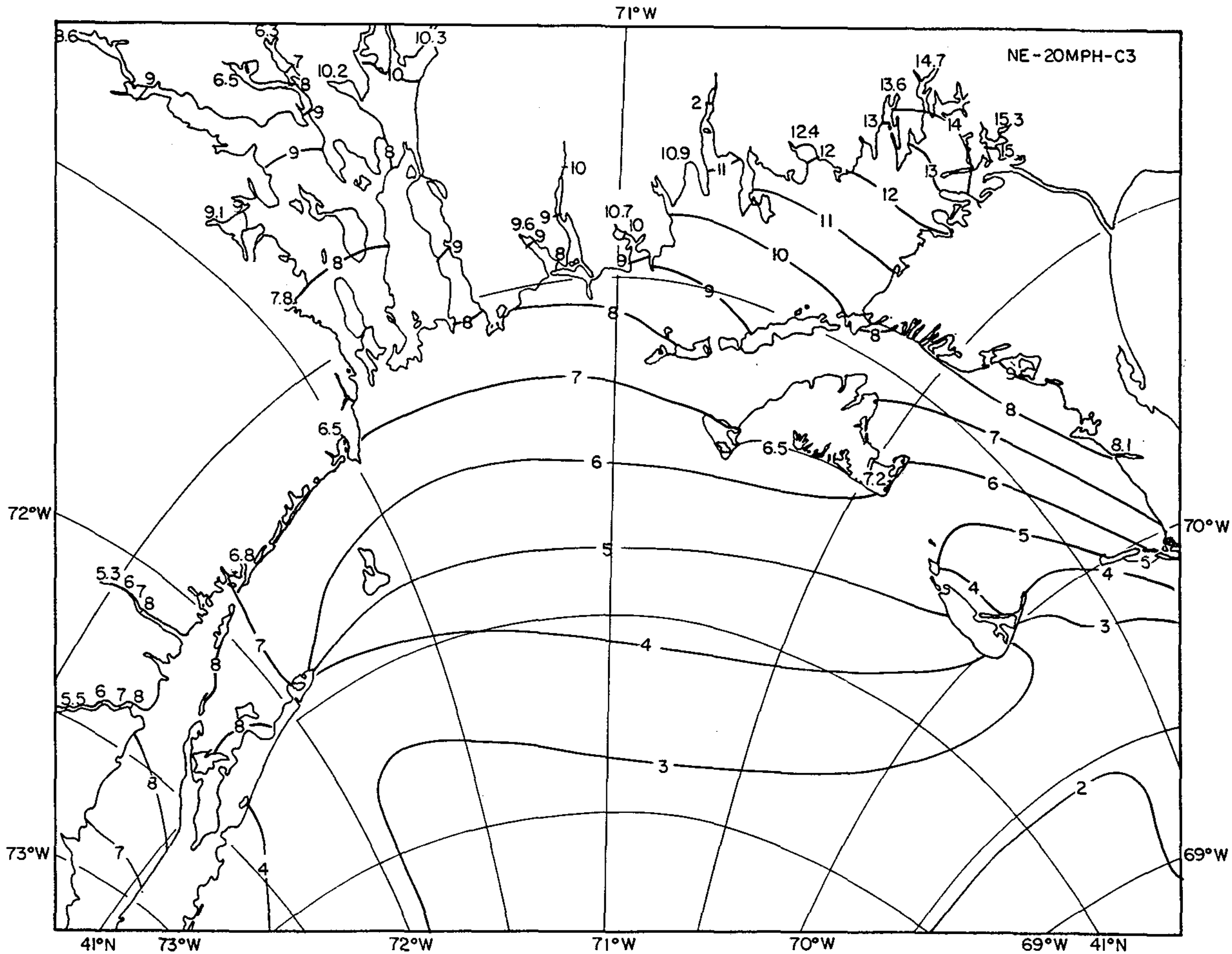
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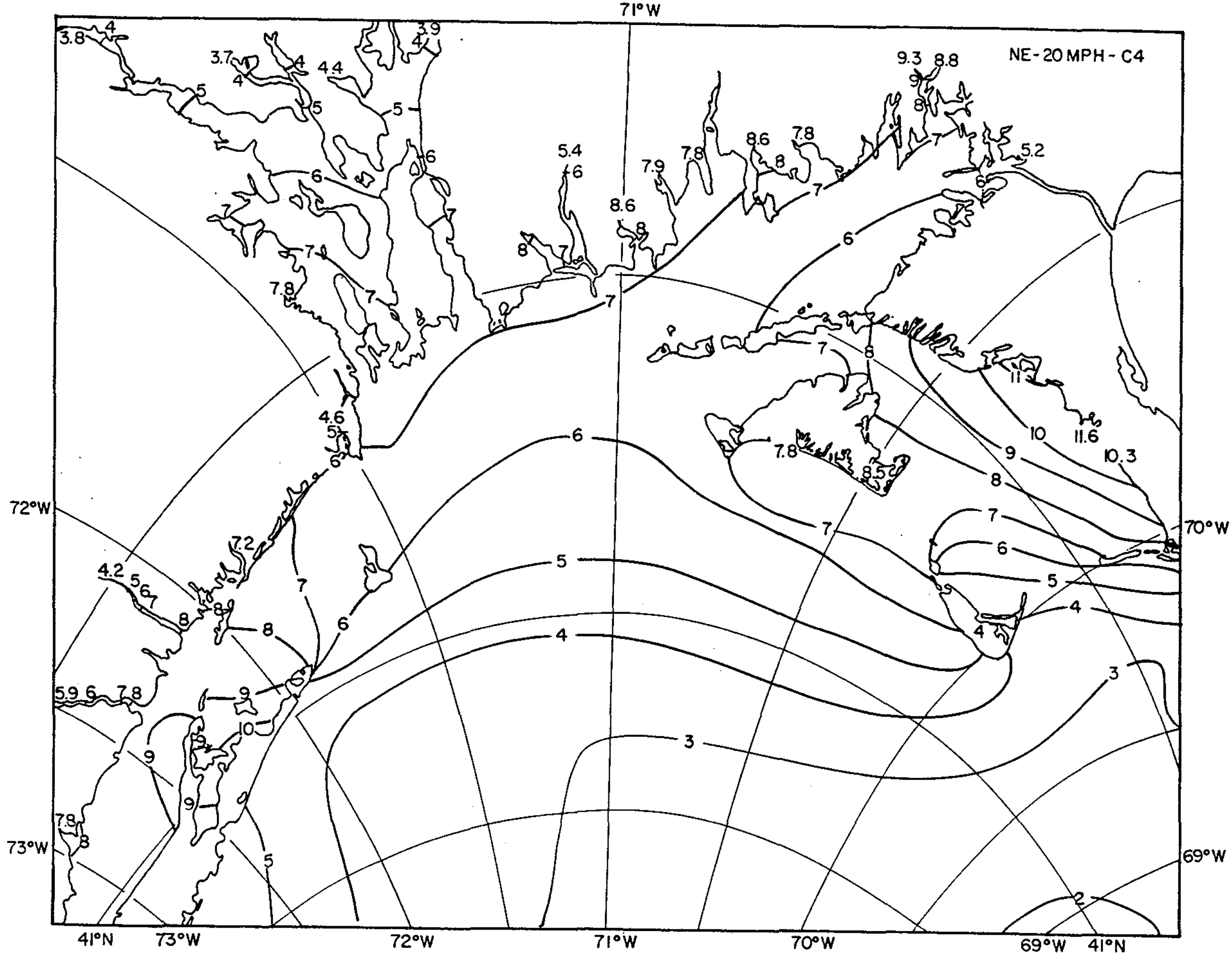
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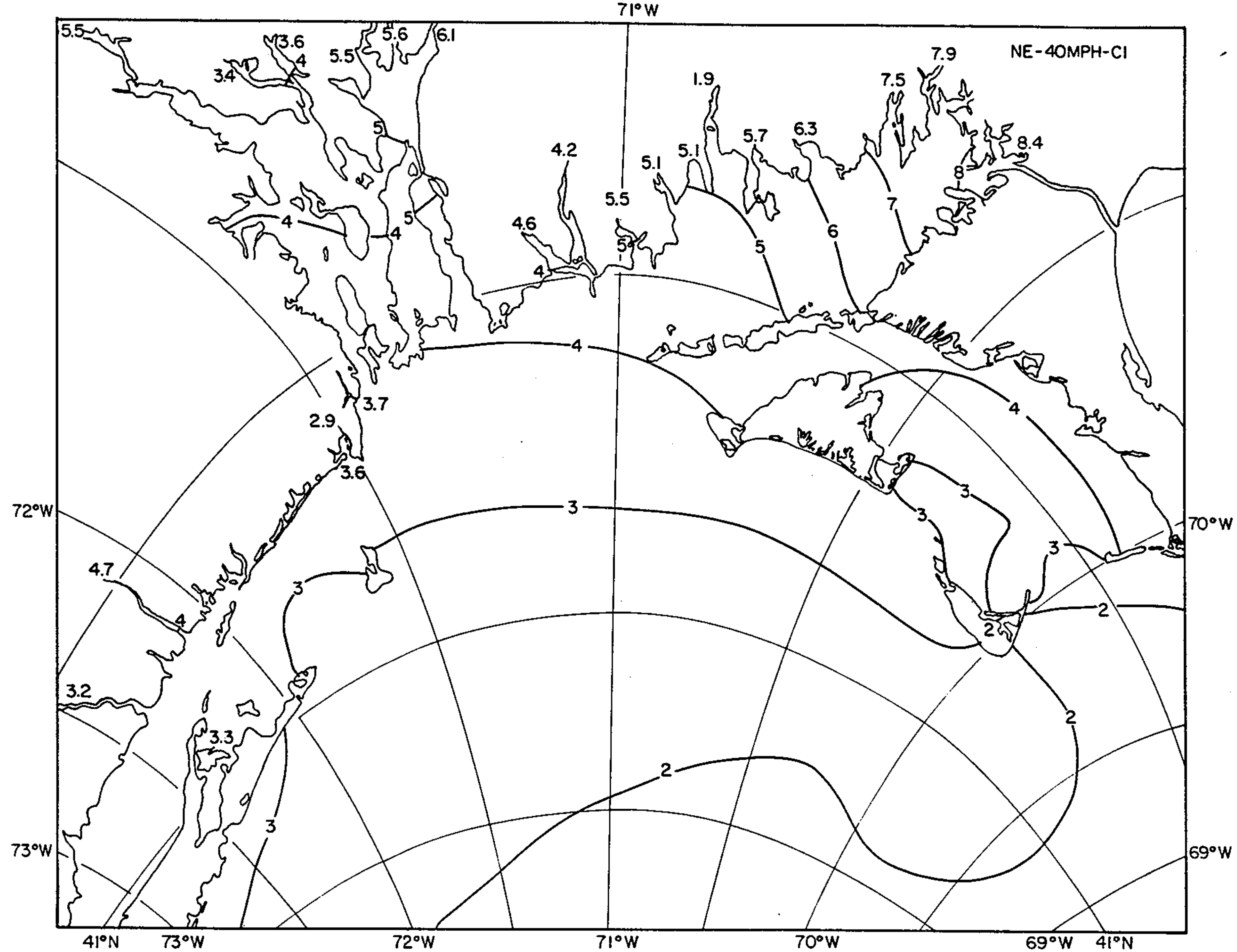
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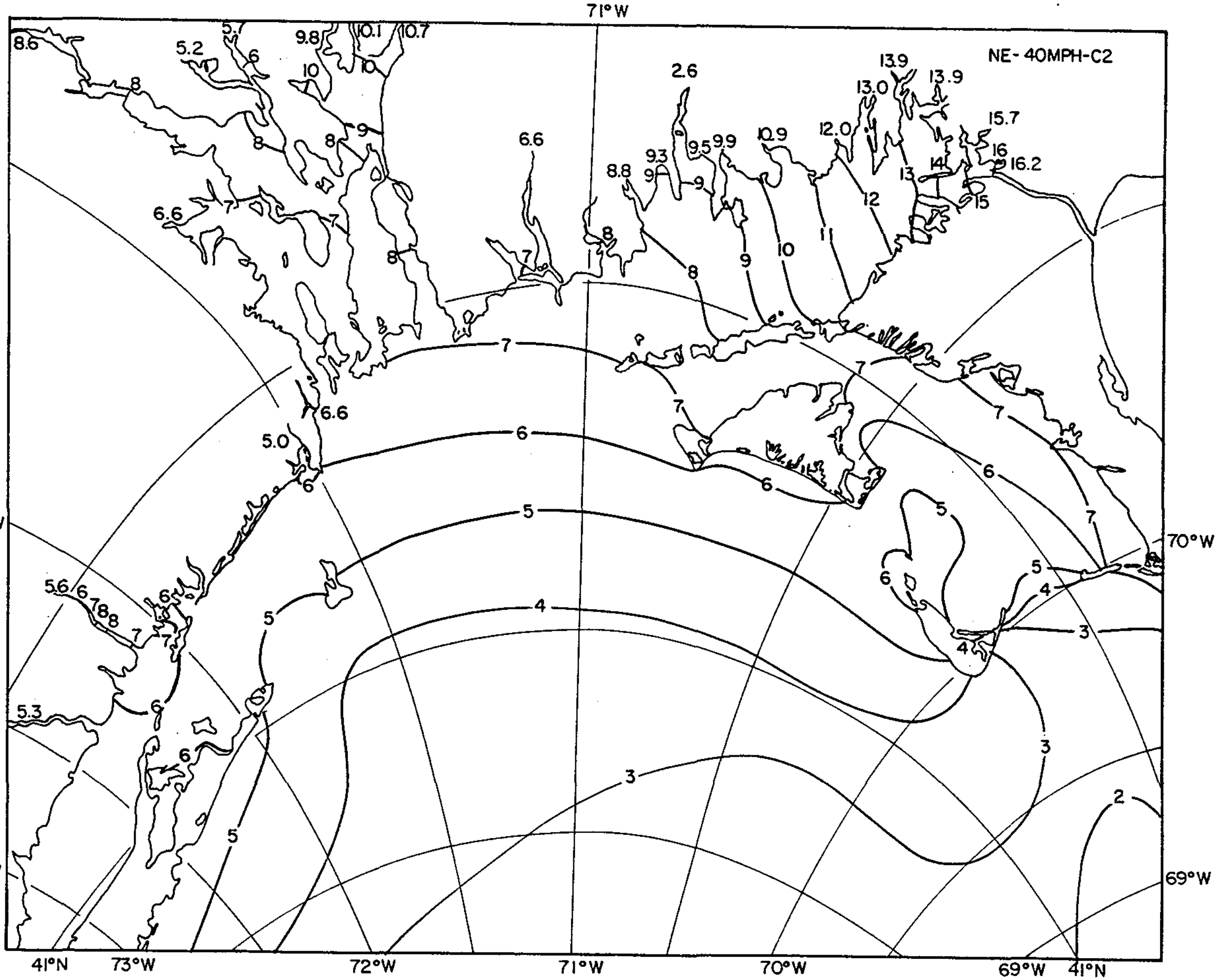
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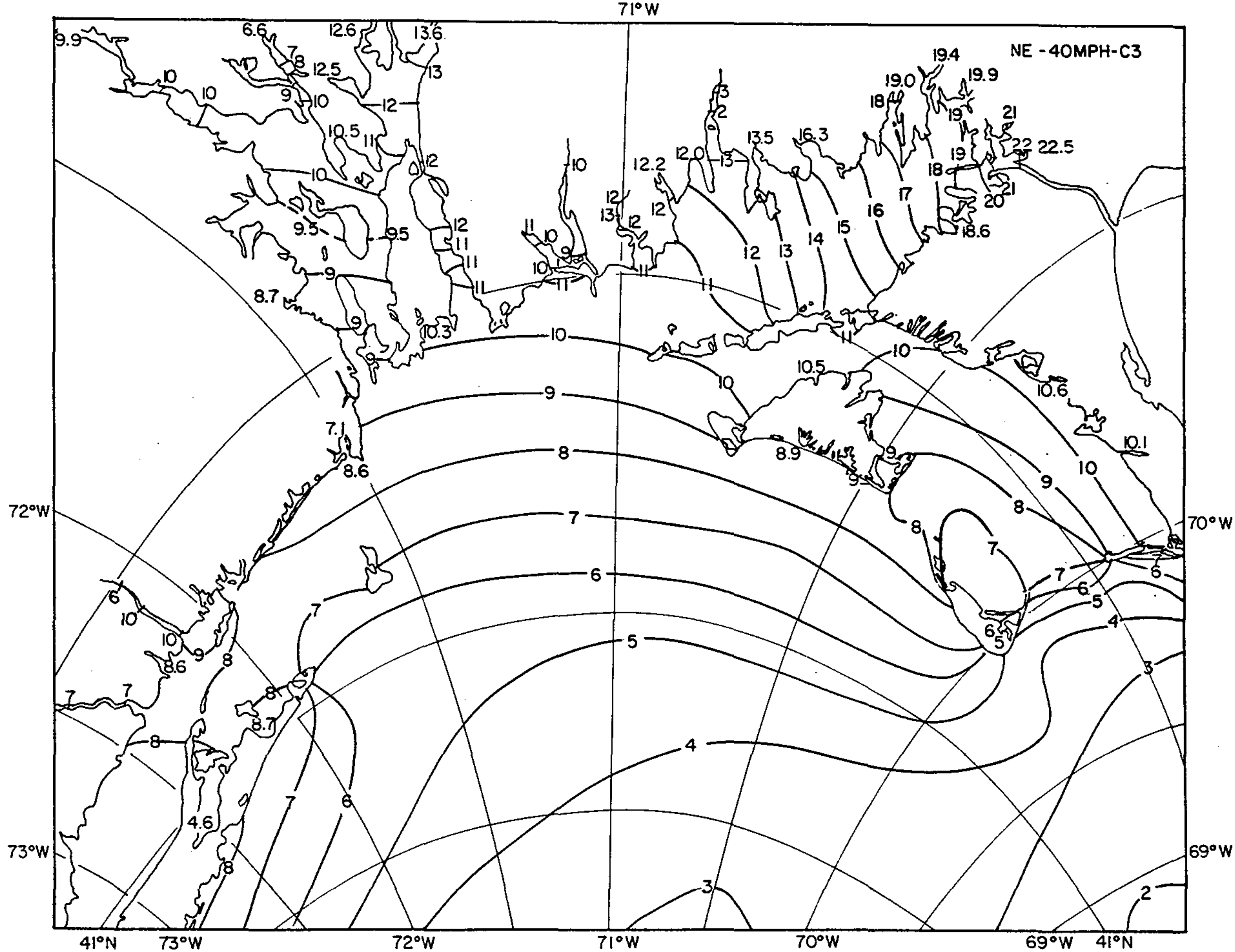
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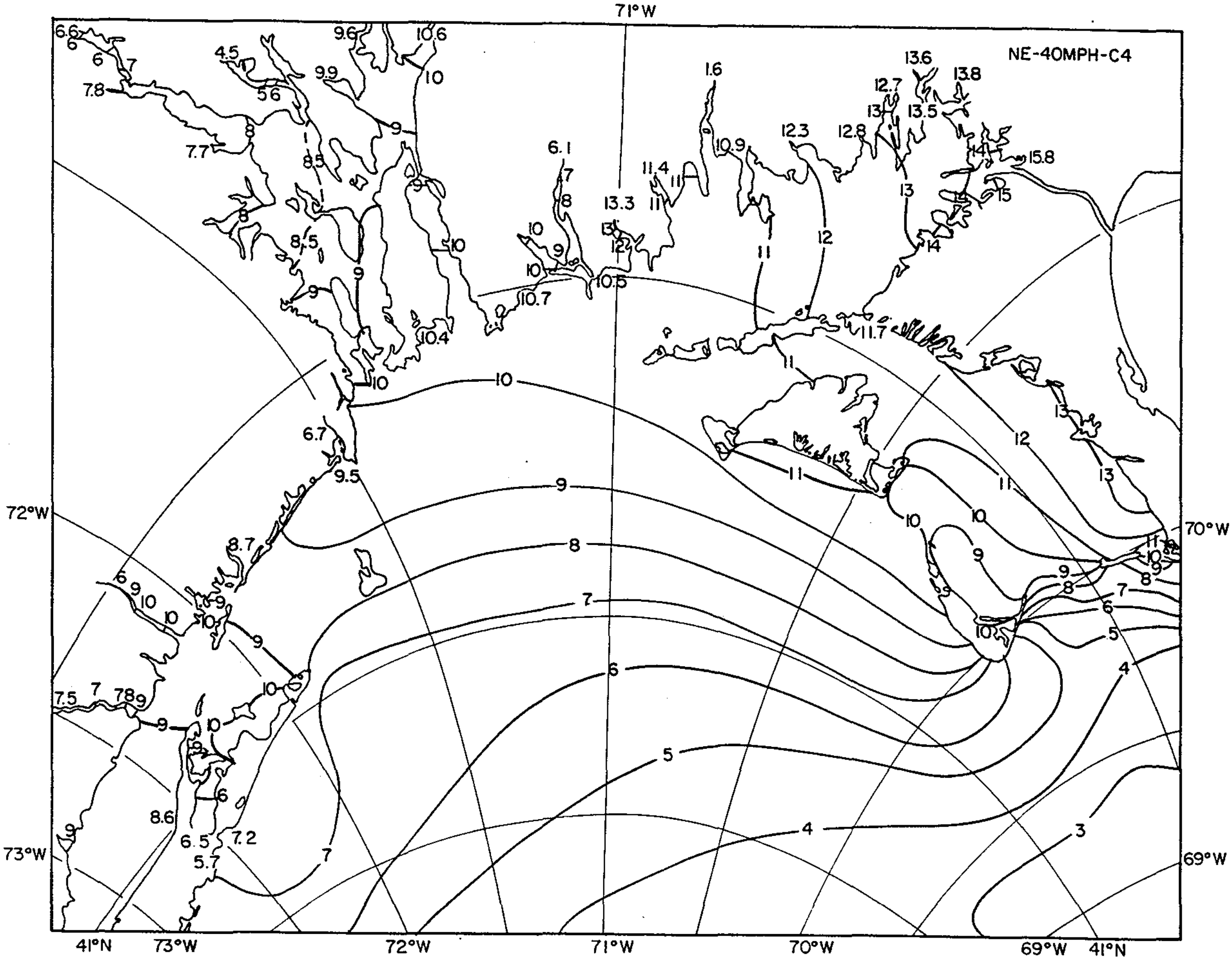
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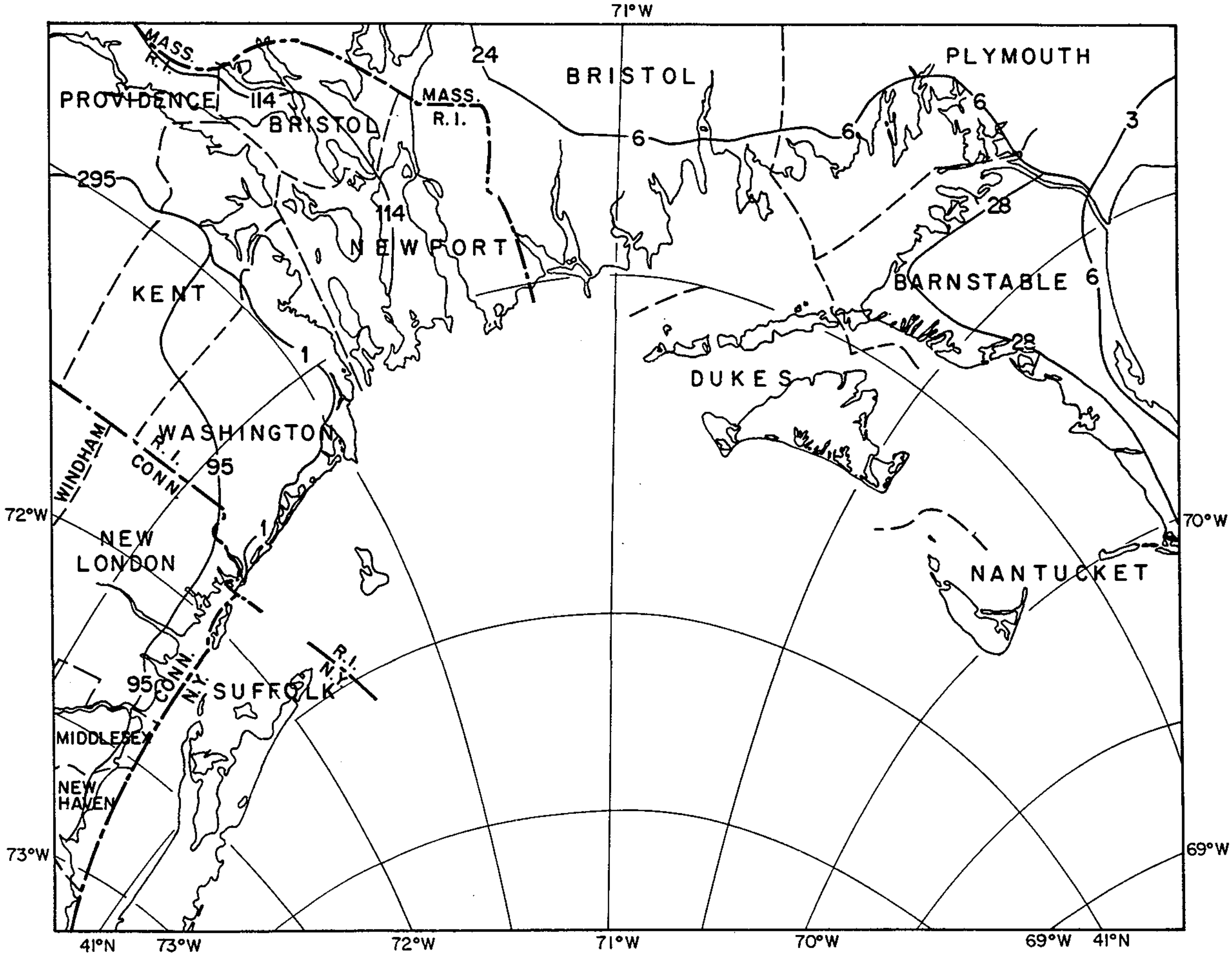

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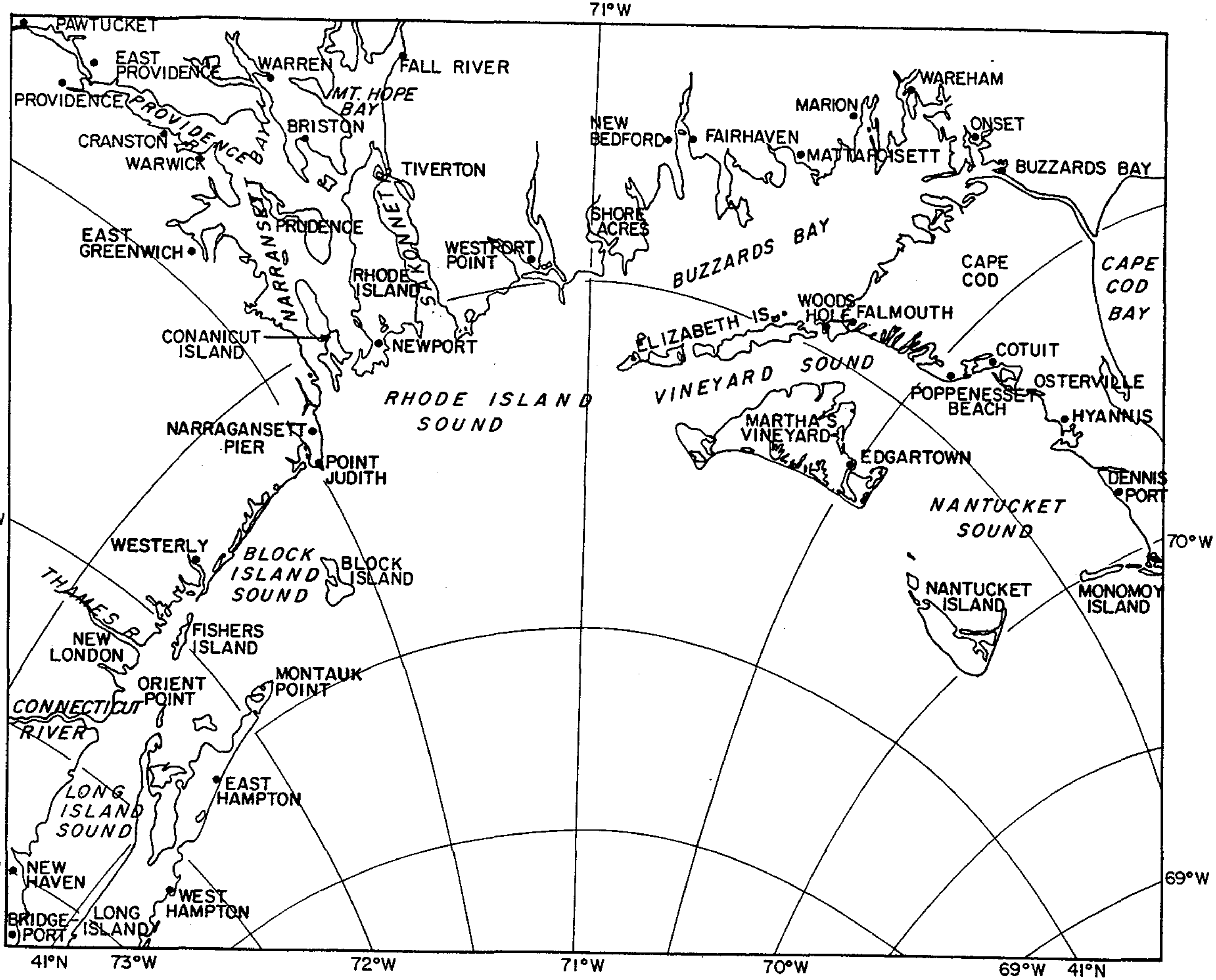
69°W
41°N



71°W
PAWTUCKET
EAST PROVIDENCE
PROVIDENCE
WARREN
FALL RIVER
MT. HOPE BAY
PROVIDENCE BAY
CRANSTON
WARWICK
BRISTON
TIVERTON
NARRANSETT
PRUDENCE
SAKONNET
EAST GREENWICH
RHODE ISLAND
WESTPORT POINT
NEW BEDFORD
FAIRHAVEN
SHORE ACRES
MARION
WAREHAM
ONSET
MATTAPOISETT
BUZZARDS BAY
BUZZARDS BAY
CAPE COD
CAPE COD BAY
ELIZABETH IS.
WOODS HOLE
FALMOUTH
CONANICUT ISLAND
NEWPORT
RHODE ISLAND SOUND
VINEYARD SOUND
COTUIT
OSTERVILLE
POPPENESSET BEACH
HYANNIS
MARTHA'S VINEYARD
EDGARTOWN
NARRAGANSETT PIER
POINT JUDITH
DENNIS PORT
NANTUCKET SOUND
72°W
70°W
WESTERLY
BLOCK ISLAND SOUND
BLOCK ISLAND
NANTUCKET ISLAND
MONOMOY ISLAND
THAMES R.
NEW LONDON
FISHERS ISLAND
ORIENT POINT
MONTAUK POINT
CONNECTICUT RIVER
LONG ISLAND SOUND
EAST HAMPTON
73°W
NEW HAVEN
69°W
WEST HAMPTON
BRIDGEPORT
LONG ISLAND
41°N
73°W
72°W
71°W
70°W
69°W
41°N

APPENDIX B

Behavioral Analysis Support Documentation

Hurricane Evacuation Behavior in the Middle Atlantic and Northeast States

Analysis of Response in Gloria, Intended Responses, and Applicability of Generalizations from other Regions

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For

U.S. ARMY CORPS OF ENGINEERS

July, 1988

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Background and Approach: Behavioral Science and Hurricane Evacuation Planning

Evacuation outcomes depend upon many factors, including how the public responds to the event, and in hurricane evacuation planning, one must make assumptions about those factors. If one makes unreasonable assumptions, an actual evacuation is unlikely to proceed as anticipated. The public responses having the greatest impact upon an evacuation are

1. The number of people who evacuate.
2. The number of vehicles used in the evacuation.
3. How promptly evacuees leave.
4. The number of evacuees who leave or attempt to leave the local area and where they go.
5. The number of evacuees who seek refuge in public shelters.

Deriving Correct Assumptions

Regardless of how detailed, formal, or quantitative an evacuation plan appears, it contains assumptions about behaviors such as those discussed above. Even if the assumptions are not deliberately and explicitly addressed, there are implicit or implied values for them. For example, planners who say they make no assumptions at all regarding whether people outside the recommended evacuation zone will evacuate are in fact assuming that none of those people will leave. Any time an evacuation plan is "tested" to ascertain the length of time required to complete an evacuation under the plan, the test includes quantitative assumptions regarding behavioral factors. The issue is not whether such assumptions should be made, because they must; the issue is what the assumptions should be.

There are at least three basic ways to derive behavioral assumptions:

1. Conduct interviews with people in a large number of locations asking what they did in multiple hurricane threats, documenting patterns of behavior under various conditions (general response model).
2. Conduct interviews asking people what they did in one particular evacuation (single event survey).
3. Conduct interviews asking people what they would do during a hurricane threat (hypothetical survey).

An Integrated Approach

Building a Quantitative General Response Model

A response model can be constructed to indicate quantitative values of specific responses, given a particular set of circumstances which the planner specifies. The extent of shadow evacuation in hurricanes, for example, can be forecast by specifying the severity of the storm, hazardousness of the neighborhood, and actions taken by public officials.

This is the heart of HMG's approach to formulating behavioral assumptions for hurricane evacuation planning. We are fortunate to have amassed actual response data from many hurricane evacuations spanning a wide geographical area and a variety of hurricane threat circumstances over a period of roughly three decades. Figure 1 shows locations where post-hurricane sample surveys have been administered. Multiple markers at a location indicates that more than one survey has been conducted.

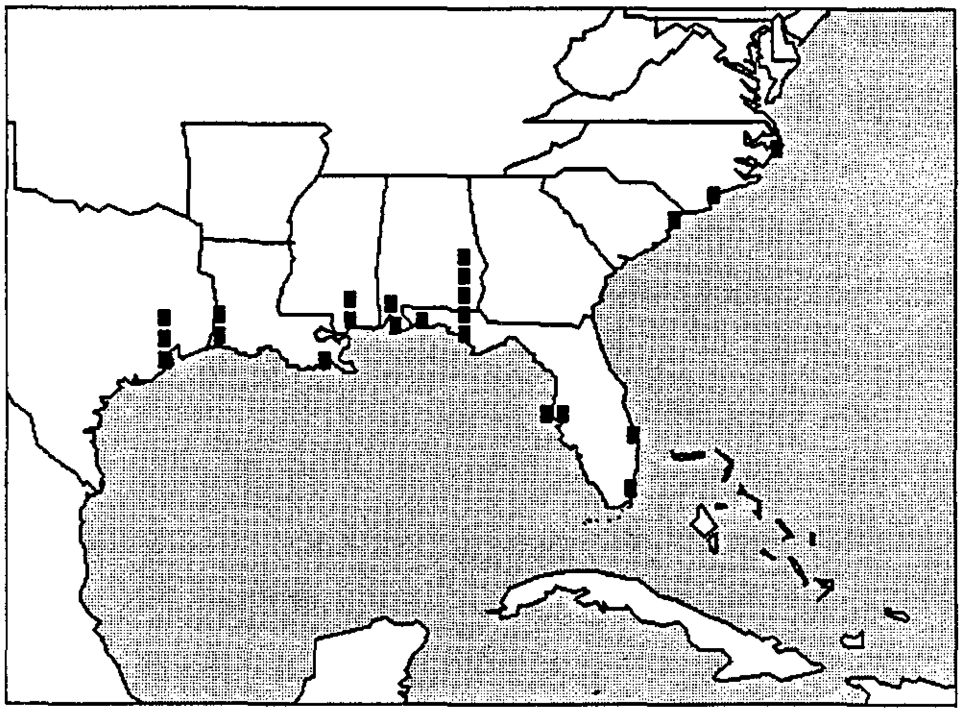


FIG. 1

HMG's general response model has been used successfully in evacuation plans along the Gulf and Atlantic coasts. Thus, for each of the behaviors to be anticipated, the model predicts a quantitative value, depending upon specific situations and circumstances specified. The structure of the general response model, including the variables affecting the principal behaviors, appears in Figure 2.

A common concern expressed about the general response model is that it is based upon responses of people in "other places" and that "our people are different." Actually the <u>strength</u> of the general model is that it accounts for differences in responses as they vary because of demographic characteristics of the population, actions by emergency management personnel, physical hazardousness of the study area, and so forth. Evidence of the model's validity lies in its history of accurately explaining and forecasting actual response behavior observed in a variety of places.

Single Event Actual Response Data

It is tempting to overgeneralize from a single evacuation in a particular location. Even the same people will respond differently in different sets of circumstances. Single event data can be very useful if not <u>over</u>used, however. If an evacuation occurs late at night, for example, and the evacuation is urgent, those circumstances tend to lead to fewer people leaving the local area than other circumstances. Thus, if the single event was a late night, urgent evacuation, it should provide an indication of the "worst case" to expect in that location for certain types of behaviors.

Single events also provide opportunities to validate the use of the general response model for forecasting in a specific location. Actual behavior in a single event can be documented and compared to that which would have been predicted

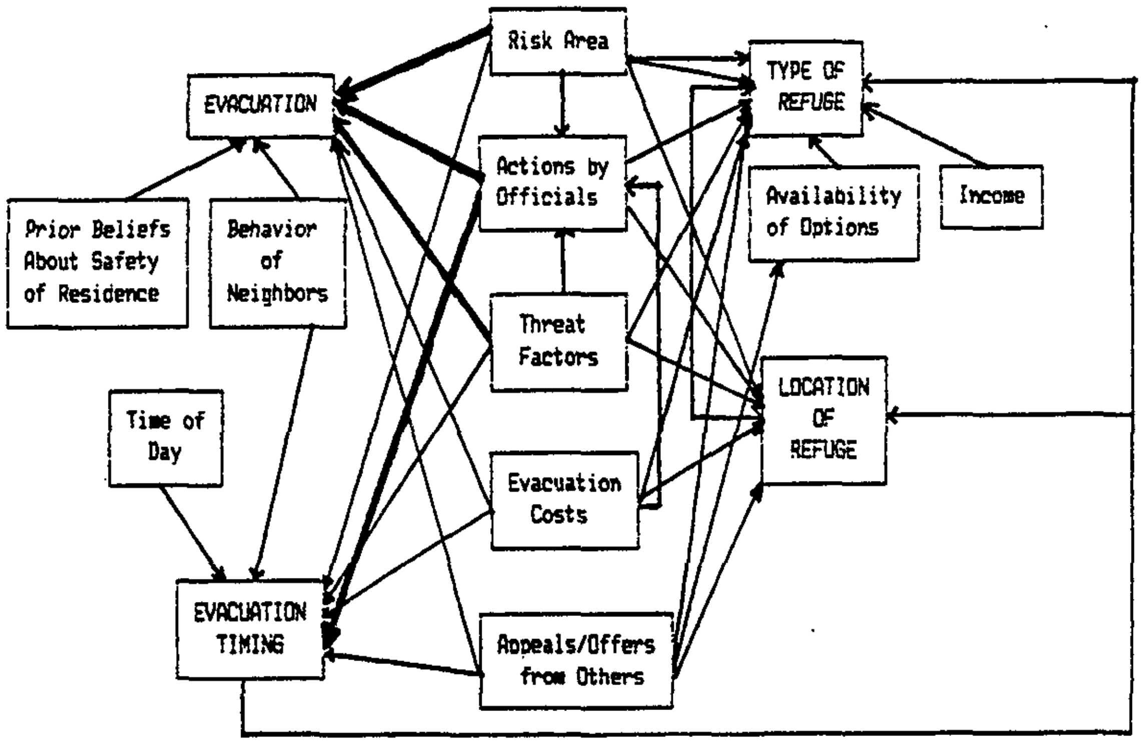

Risk Area
EVACUATION
TYPE OF REFUGE
Actions by Officials
Availability of Options
Income
Prior Beliefs About Safety of Residence
Behavior of Neighbors
Threat Factors
LOCATION OF REFUGE
Time of Day
Evacuation Costs
EVACUATION TIMING
Appeals/Offers from Others

FIG. 2

by the general response model. Its "fit" gives a clue to how much the model would have to be adjusted to work for the specific location and hazard.

Single event data was collected in this study documenting how residents responded during hurricane Gloria in 1985. This marks the first time actual response data has been collected systematically in the study area. The Gloria results will be compared to patterns predicted by the general response model to assess the model's applicability to the region. It is tempting to overgeneralize from any single evacuation, and response to future hurricane threats could vary substantially from the Gloria findings.

Hypothetical Responses

Although hypothetical response data can hardly ever be used literally for quantitative forecasts, HMG has collected much data of this nature, and it does have utility in experienced, knowledgeable hands. There are certain consistent biases in hypothetical response data, for example. People are more likely to say they would evacuate in "low risk" situations than they usually do, more likely to say they would leave early than they usually do, and more likely to say they would use public shelters than they usually do. Hypothetical response data can be adjusted to account for those sorts of known biases. Hypothetical data in one location can be compared with that collected elsewhere for an indication of relative variation between the samples. If more people in one location say they would refuse to leave than in another, they probably really are more likely to refuse. At least more effort will be required to have them move. So, although the magnitude of people saying they wouldn't leave might not be quantitatively valid, it at least gives a relative indication. This can be particularly useful when actual response data is also available in the second location.

Many respondents to the Gloria survey did not evacuate in response to the threat. That information is useful in assessing evacuation rates forecast by the general response model, but provides no information concerning other behaviors such as shelter use by those respondents. Therefore residents not evacuating in Gloria were asked hypothetical questions about what they believe they would do in future hurricane threats or what they would have done if they had evacuated in Gloria. The hypothetical responses will be compared to intended response data collected elsewhere and to actual response by other respondents in Gloria.

Vacationers

Unfortunately, the general response model is well developed only for residents. Actual response data is virtually nonexistent concerning how tourists, including RV operators, respond during hurricane threats.

HMG collected hypothetical response data with many vacationers in both North and South Carolina, but that data has most of the same weaknesses as hypothetical response data from residents. In addressing vacationer response we base most of our conclusions upon interviews conducted with tourism officials, hotel/motel managers, and campground operators following hurricane threats elsewhere.

Purpose of This Report

Methodology and results of the post-Gloria survey will be presented in the following sections of this report. Findings for all 19 survey sites will be included, with consistencies and differences noted among sites. The results will be compared to results normally observed in other hurricane prone areas to assess the applicability of the general response model to the study area. The survey data will be used in supplementary reports for each state to refine the general response model if necessary for use in deriving planning assumptions for each state.

Survey Methodology

Sampling

Corps of Engineers representatives from Norfolk, Baltimore, Philadelphia, New York, and New England districts worked with HMG and state and local emergency management officials to select survey sites and sample sizes in each state from Virginia through Massachusetts. Criteria for selection varied from state to state, but in most instances the locations were important in and of themselves because of evacuation concerns at those sites or because the places were representative of other areas to which generalizations could be extended. The sample sites are displayed in Figure 3.

Virginia Beach, Virginia

Approximately 100 telephone interviews were completed with households having telephone prefixes 420, 427, and 428. Phone numbers were selected from the local telephone directory.

Norfolk, Virginia

Approximately 100 telephone interviews were completed with households having telephone prefixes 480, 489, 583, 587, and 588. Phone numbers were selected from the local telephone directory.

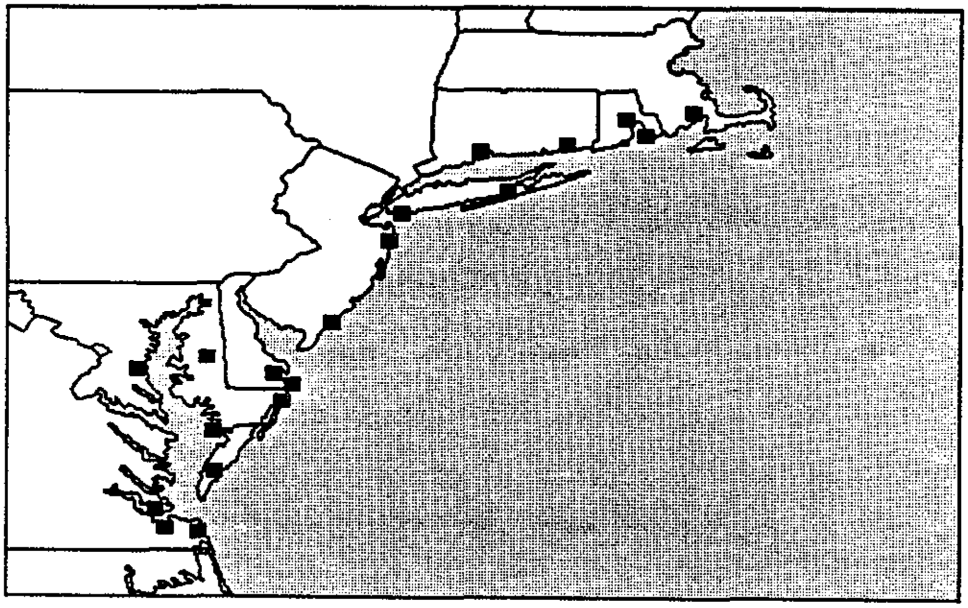


Fig. 3

Newport News, Virginia

Approximately 100 telephone interviews were completed with households having telephone prefixes 245 at addresses south of 39th street and east of Jefferson Avenue. Phone numbers were selected from the local telephone directory.

Virginia Eastern Shore

Approximately 100 telephone interviews were completed with households in a number of Northampton and Accomack County towns suggested by local emergency management officials. Phone numbers were selected from the local telephone directory after cross referencing the addresses with elevation maps of the area. Predominant prefixes were 331, 787, 442, 336, 824, and 891.

Chrisfield, Maryland

Approximately 100 telephone interviews were completed with households having telephone prefix 968 and having a Chrisfield address. Phone numbers were selected from the local telephone directory.

Anne Arundel County, Maryland

Approximately 100 telephone interviews were completed with households having telephone prefixes 741, 798, 867 and having an address in one of several specific towns on or near Chesapeake Bay south of Annapolis (including Deale, Avalon Shores, Rose Haven). Phone numbers were selected from the local telephone directory.

Denton, Maryland

Approximately 100 telephone interviews were completed with households having telephone prefix 479 and having an address in Denton or West Denton. Phone numbers were selected from the local telephone directory.

Ocean City, Maryland

Approximately 100 telephone interviews were completed with households having telephone prefixes 250, 289, 524, 723 and having an address in Ocean City. Phone numbers were selected from the local telephone directory.

Delaware "Beach"

Approximately 100 telephone interviews were completed with households having telephone prefix 539 and having an address in Bethany Beach or South Bethany. Phone numbers were selected from the local telephone directory.

Delaware "Mainland"

Approximately 100 telephone interviews were completed with households having telephone prefix 945, which included Millsboro and nearby towns. Phone numbers were selected from the local telephone directory.

"Southern" New Jersey

Approximately 100 telephone interviews were completed with households in Ocean City having telephone prefixes 390, 391, 398, and 399. Phone numbers were selected from the local telephone directory.

"Northern" New Jersey

Approximately 100 telephone interviews were completed with households in Ocean Grove, Bradley Beach, and Avon having telephone prefixes 774, 775, 776, 918, 922, and 988. Phone numbers were selected from the local telephone directory.

"Rockaway" New York

Approximately 200 telephone interviews were completed with households in the Far Rockaway, Belle Harbor, Edgemere areas of Queens. The area is referred to as Zone 13 in the NYNEX directory and includes several prefixes (318, 327, 337, 471, 474, 634, and 945). Phone numbers were selected from the local telephone directory.

"Suffolk" New York

Approximately 200 telephone interviews were completed with households in Quoge and Westhampton Beach in Suffolk County on Long Island (with prefixes 635 and 288). Phone numbers were selected from the local telephone directory.

"Fairfield" Connecticut

Approximately 100 telephone interviews were completed with households in Fairfield, Bridgeport, Stratford, and Milford. Phone numbers were selected from Hill-Donnelly directories after identifying streets from maps provided by the New England District showing Category 2 surge inundation areas.

"Groton" Connecticut

Approximately 100 telephone interviews were completed with households in Groton, Stonington, and Mystic. Phone numbers were selected from Hill-Donnelly directories after identifying streets from maps provided by the New England District showing Category 2 surge inundation areas.

Warwick, Rhode Island

Approximately 100 telephone interviews were completed with households in Warwick. Phone numbers were selected from the Polk directory after identifying streets from Flood Insurance maps provided by the New England District.

Newport, Rhode Island

Approximately 100 telephone interviews were completed with households in Newport. Phone numbers were selected from the Cole directory after identifying streets from Flood Insurance maps provided by the New England District.

Wareham, Massachusetts

Approximately 100 telephone interviews were completed with households in Wareham. Phone numbers were selected from the New Bedford and vicinity Cole directory after identifying streets from Flood Insurance maps provided by the New England District.

Sample Size Considerations

There is always some probability of error when generalizing from a sample to the larger population from which it was drawn. If 100 residents of the surge prone area of Warwick, Rhode Island are selected randomly and interviewed, those 100 people are referred to as a sample. All people living within the Warwick surge zone from which the sample was selected constitute the population to which we attempt to generalize from information gained only from the sample.

A sample of 100 provides figures which, 90% of the time, will be within 5 to 8 percentage points of the actual population values. A sample of 200 will be within 3 to 5 percentage points of the true population value 90% of the time. This is true even if the population includes millions of people. For some purposes such small samples are not adequately reliable. In this case, however, the survey data is but one component in a broader, more important methodology and provides sufficient precision for the comparative purposes intended for it. The responses obtained in this survey are compared to response patterns observed under the general response model to assess whether the two are generally consistent. Small differences are not of consequence.

One should be especially cautious when generalizing from subsets of the samples of 100. For example, in many locations only about a third of the respondents evacuated. Therefore, in those sites only about 35 people were asked what sort of shelter they used. Answers based on interviews with 35 people are usually reliable within only 11 percentage points, which is a substantial margin of uncertainty.

One point to keep in mind, therefore, is that sample differences are not necessarily indicative of differences within the population. For example, if 70% of 100 respondents in one site left the local area when evacuating in Gloria, and only 60% of 100 respondents in a second site left the local area, that would probably not be sufficient evidence to conclude that people in the former location were more likely overall to leave the local area than people in the latter location. Figures of 70% and 50%, however, would usually indicate population differences in that example.

At times it is useful to ascertain whether, for example, wealthy evacuees were any less likely to use public shelters than low income evacuees. To answer those sorts of questions reliably, samples must sometimes be fairly large.

Therefore, to analyze those kinds of crosstabulations, the individual site samples will be aggregated in this report. Samples from Virginia through New Jersey are lumped into a single group which will be referred to as the southern sample, and New York through Massachusetts are grouped into a northern sample.

In all the tables presenting survey results, sample sizes are included. The reader is advised to always note the sample size before deciding how much confidence to place in a particular result.

Interview Questions

The questions asked of respondents are included as Appendix I. Questions 8a, 14a, 16a, 17a, and 17b were asked in the northern area only. Question 17 was asked in both areas, but in the northern area the response categories were made more specific.

Sample Characteristics

Age

Four questions were asked which could provide background information useful in explaining variations in response to Gloria and to the hypothetical questions. Figure 4 shows the age distribution of respondents across the 19 sites. From a behavioral perspective the most meaningful age group is probably people over 65. At a few of the sites a third of the sample is over 65. Warwick has the smallest percentage (10%) over 65.

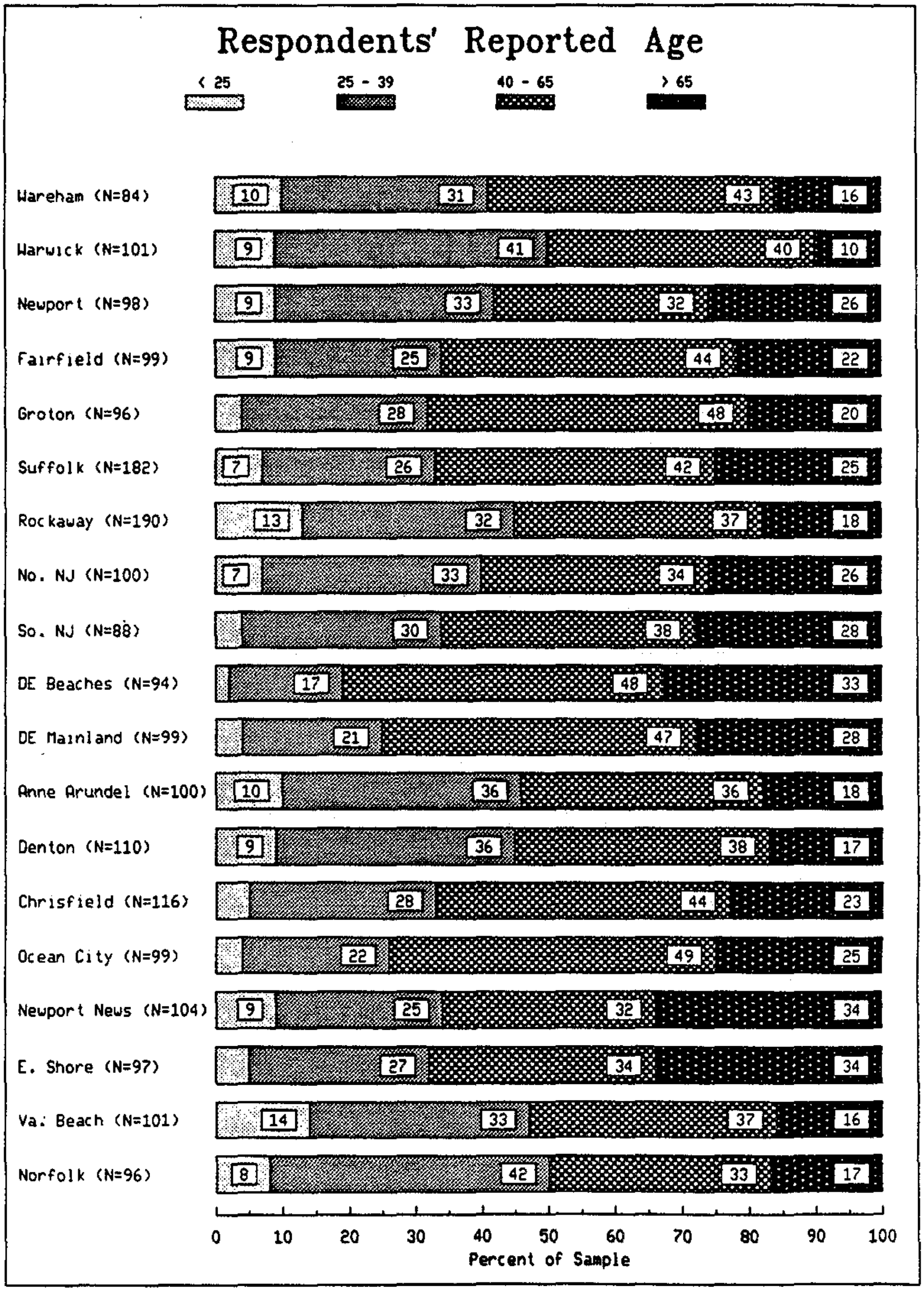
Income

Respondents were asked to indicate which of five categories described their annual family income. Income categories were used to make the information less specific and therefore to increase the willingness to provide the information. Nevertheless roughly 15% of the respondents refused to reveal their income. Moreover, there is no way of knowing whether other respondents were candid and accurate in their responses.

Based upon answers provided, Figure 5 indicates incomes at the 19 sites. Chrisfield, MD and Newport News, VA had the greatest incidence of low income interviewees. More than a third in those locations reported incomes below $10,000.

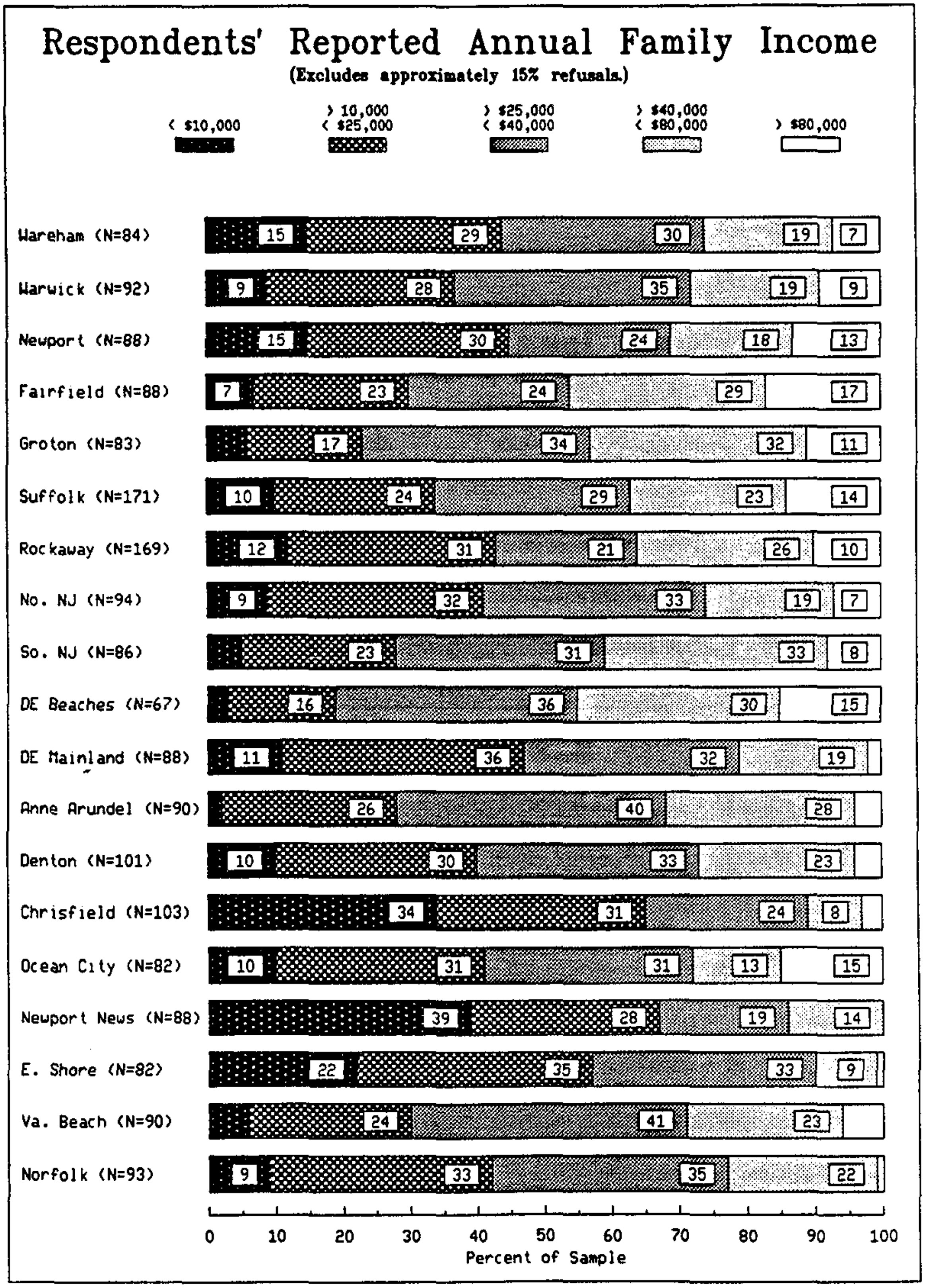
Housing

The vast majority of respondents lived in single-family detached housing units (Figure 6). The only two exceptions were Rockaway, NY were 39% said they lived in high-rise apartments and on the Delaware mainland where 55% lived in



Respondents' Reported Age
< 25
25 - 39
40 - 65
> 65
Wareham (N=84)
10
31
43
16
Warwick (N=101)
9
41
40
10
Newport (N=98)
9
33
32
26
Fairfield (N=99)
9
25
44
22
Groton (N=96)
28
48
20
Suffolk (N=182)
7
26
42
25
Rockaway (N=190)
13
32
37
18
No. NJ (N=100)
7
33
34
26
So. NJ (N=88)
30
38
28
DE Beaches (N=94)
17
48
33
DE Mainland (N=99)
21
47
28
Anne Arundel (N=100)
10
36
36
18
Denton (N=110)
9
36
38
17
Chrisfield (N=116)
28
44
23
Ocean City (N=99)
22
49
25
Newport News (N=104)
9
25
32
34
E. Shore (N=97)
27
34
34
Va. Beach (N=101)
14
33
37
16
Norfolk (N=96)
8
42
33
17
0 10 20 30 40 50 60 70 80 90 100
Percent of Sample

FIG. 4



Respondents' Reported Annual Family Income
(Excludes approximately 15% refusals.)
< $10,000
> 10,000 < $25,000
> $25,000 < $40,000
> $40,000 < $80,000
> $80,000
Wareham (N=84) 15 29 30 19 7
Warwick (N=92) 9 28 35 19 9
Newport (N=88) 15 30 24 18 13
Fairfield (N=88) 7 23 24 29 17
Groton (N=83) 17 34 32 11
Suffolk (N=171) 10 24 29 23 14
Rockaway (N=169) 12 31 21 26 10
No. NJ (N=94) 9 32 33 19 7
So. NJ (N=86) 23 31 33 8
DE Beaches (N=67) 16 36 30 15
DE Mainland (N=88) 11 36 32 19
Anne Arundel (N=90) 26 40 28
Denton (N=101) 10 30 33 23
Chrisfield (N=103) 34 31 24 8
Ocean City (N=82) 10 31 31 13 15
Newport News (N=88) 39 28 19 14
E. Shore (N=82) 22 35 33 9
Va. Beach (N=90) 24 41 23
Norfolk (N=93) 9 33 35 22
0 10 20 30 40 50 60 70 80 90 100
Percent of Sample

FIG. 5

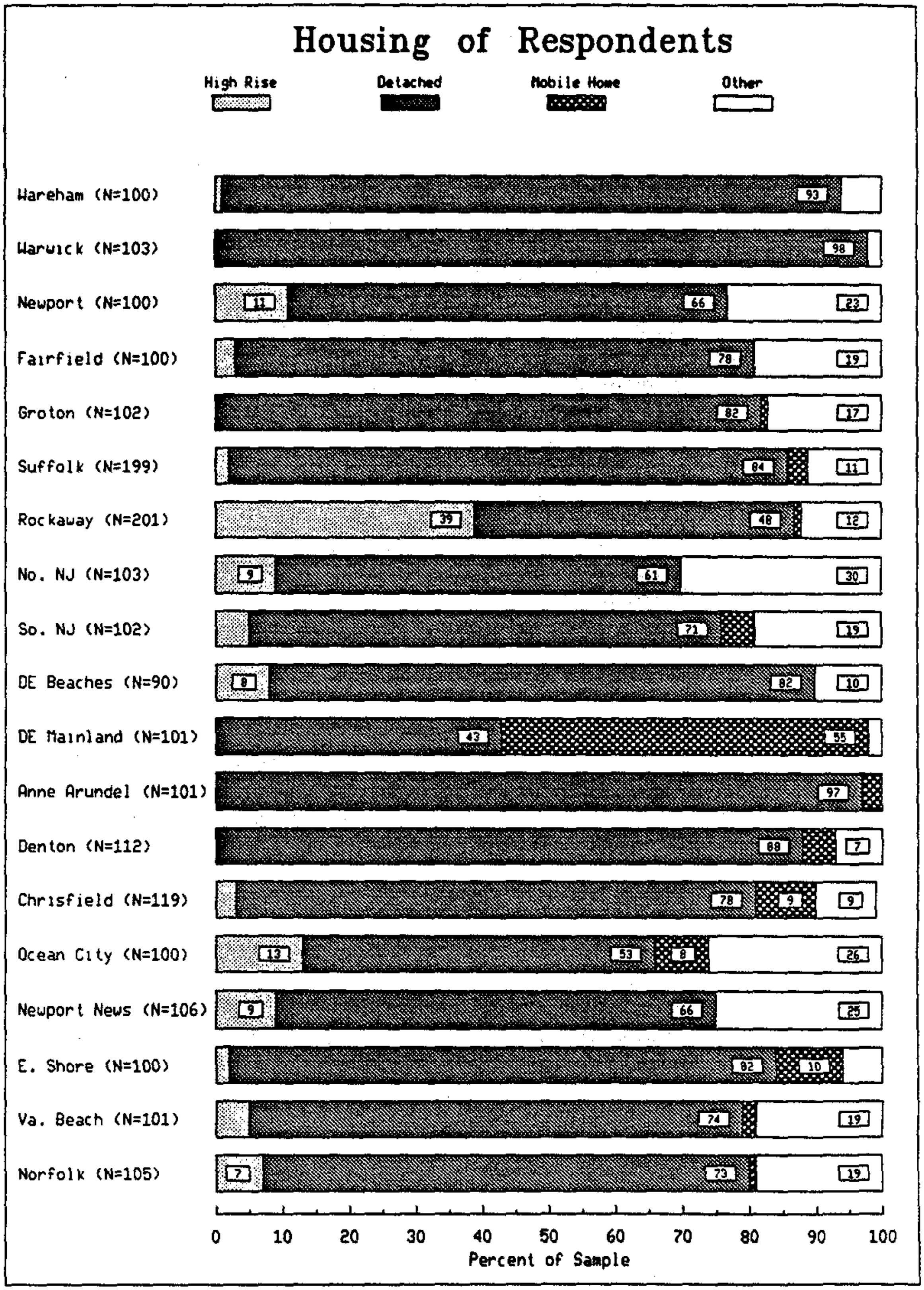

Housing of Respondents
High Rise
Detached
Mobile Home
Other
Wareham (N=100)
Warwick (N=103)
Newport (N=100)
Fairfield (N=100)
Groton (N=102)
Suffolk (N=199)
Rockaway (N=201)
No. NJ (N=103)
So. NJ (N=102)
DE Beaches (N=90)
DE Mainland (N=101)
Anne Arundel (N=101)
Denton (N=112)
Chrisfield (N=119)
Ocean City (N=100)
Newport News (N=106)
E. Shore (N=100)
Va. Beach (N=101)
Norfolk (N=105)
93
98
11
66
23
78
19
82
17
84
11
39
48
12
9
61
30
71
19
8
82
10
43
55
97
88
7
78
9
9
13
53
8
26
9
66
25
82
10
74
19
7
73
19
0
10
20
30
40
50
60
70
80
90
100
Percent of Sample

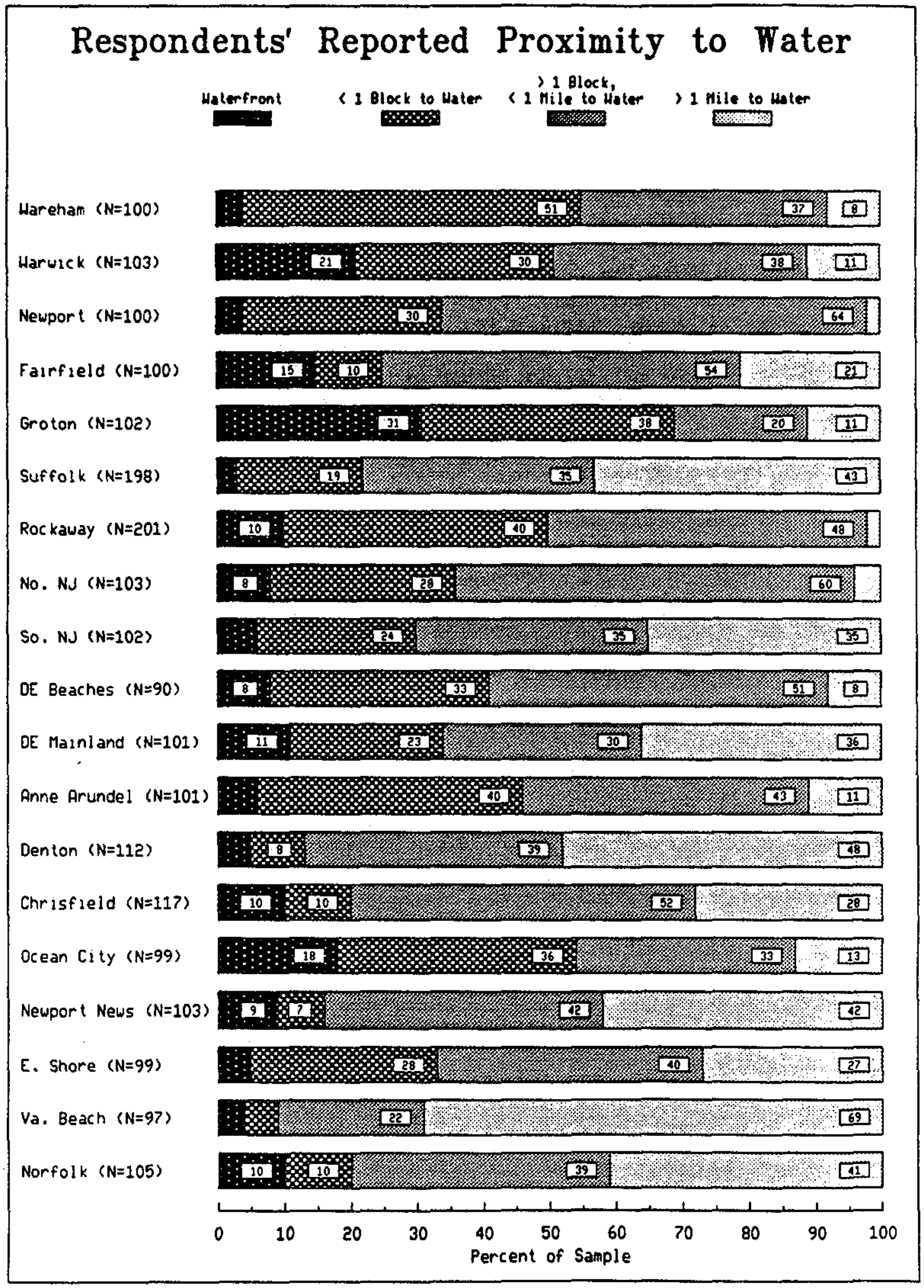
FIG. 6

mobile homes. "Other" refers primarily to duplexes and medium density apartments or condos.

Proximity to Water

The sample sites themselves vary in terms of flooding propensity and proximity to water, but there is also variation within the sites (Fig. 7). At most interview locations between 25% and 50% of the respondents said they lived within a block of a water body (ocean, harbor, bay, sound). As many as 31% (Groton) said they lived adjacent to such a water body. Many of the sites also had a substantial portion of the respondents living more than a mile from any water.

To some extent measurement of this variable is subject to judgment on the part of people answering the question. Most people underestimate distances, for example, so some of the individuals saying they lived more than a block but less than a mile from water might actually live more than a mile from water. Overall, though, it's reasonable to assume that most people in the "more than a mile" category are in fact farther from water than most in the other categories.



Respondents' Reported Proximity to Water
Waterfront
< 1 Block to Water
> 1 Block, < 1 Mile to Water
> 1 Mile to Water
Wareham (N=100)
Warwick (N=103)
Newport (N=100)
Fairfield (N=100)
Groton (N=102)
Suffolk (N=198)
Rockaway (N=201)
No. NJ (N=103)
So. NJ (N=102)
DE Beaches (N=90)
DE Mainland (N=101)
Anne Arundel (N=101)
Denton (N=112)
Chrisfield (N=117)
Ocean City (N=99)
Newport News (N=103)
E. Shore (N=99)
Va. Beach (N=97)
Norfolk (N=105)
0 10 20 30 40 50 60 70 80 90 100
Percent of Sample

FIG. 7

Evacuation

In only 5 of the 19 survey sites did a majority of respondents evacuate: Delaware beaches, Delaware mainland, Ocean City, MD, Southern New Jersey, and Warwick, RI (Figure 8). Denton, MD had by far the lowest evacuation rate (8% and too small to break down in a number of subsequent figures). These figures alone, however, are not useful in evaluating the applicability of the general response model to the region. For that, response variations in the sample must be analyzed.

Reasons Given for Evacuating

Figure 9 depicts the reasons given for leaving. It should be noted that these answers were in response to an open-ended question in which people simply volunteered reasons. Asking specifically whether each factor played a role in their decision to leave would have almost certainly resulted in more people attributing their decision to these factors.

It should also be noted that this is not the most reliable procedure for ascertaining what actually determined evacuation behavior. Most people are poor at articulating the factors which truly cause their behavior.

Reasons fall into two general types of response: information sources and information itself. Most evacuees in all 19 sites indicated that they left because of information from public officials, the National Weather Service, police, media, or friends and relatives. The proportions vary from place to place, but the media was mentioned more than other sources in most locations.

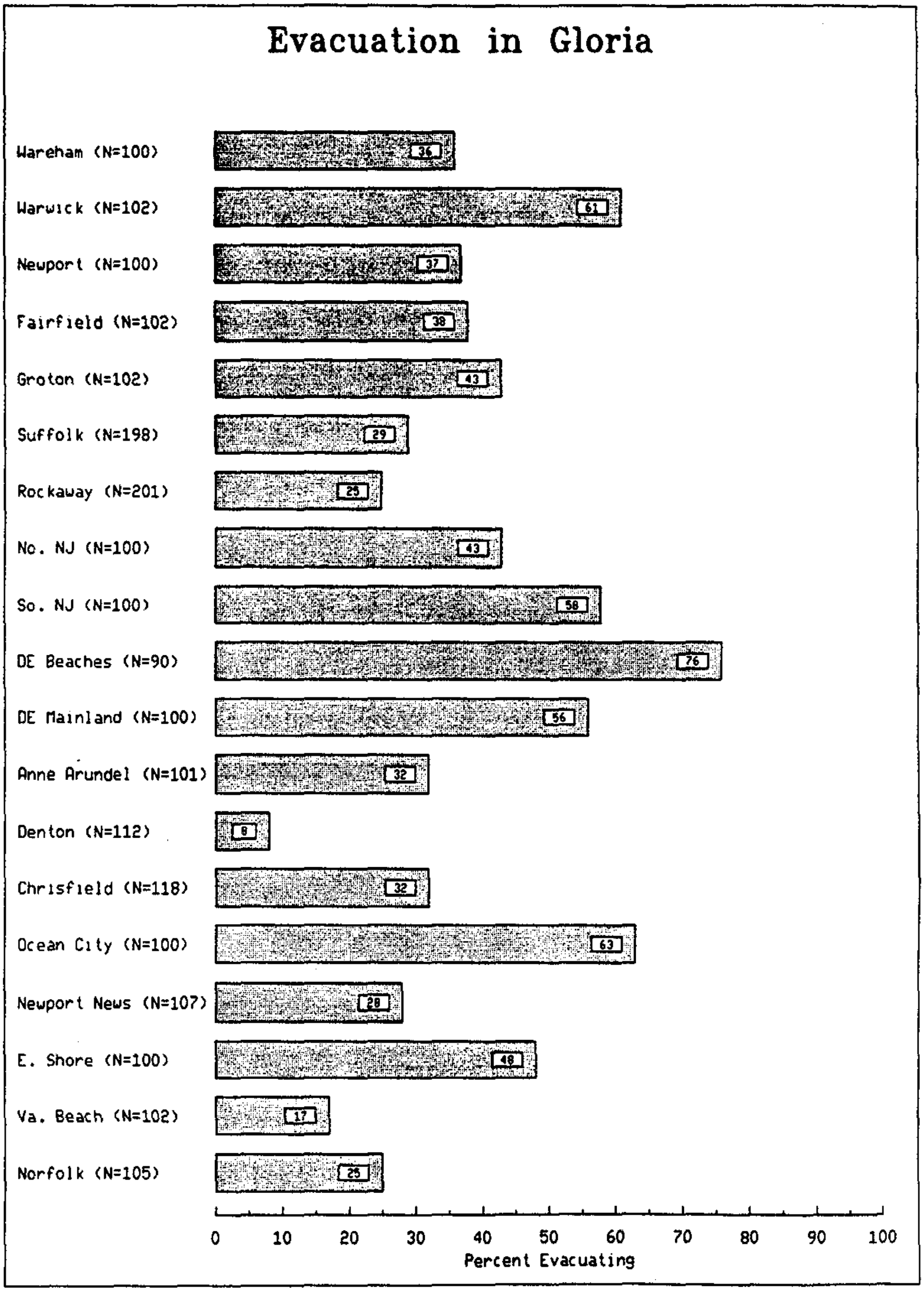

Evacuation in Gloria
Wareham (N=100)
Warwick (N=102)
Newport (N=100)
Fairfield (N=102)
Groton (N=102)
Suffolk (N=198)
Rockaway (N=201)
No. NJ (N=100)
So. NJ (N=100)
DE Beaches (N=90)
DE Mainland (N=100)
Anne Arundel (N=101)
Denton (N=112)
Chrisfield (N=118)
Ocean City (N=100)
Newport News (N=107)
E. Shore (N=100)
Va. Beach (N=102)
Norfolk (N=105)
36
61
37
38
43
29
25
43
58
76
56
32
8
32
63
28
48
17
25
0
10
20
30
40
50
60
70
80
90
100
Percent Evacuating

FIG. 8

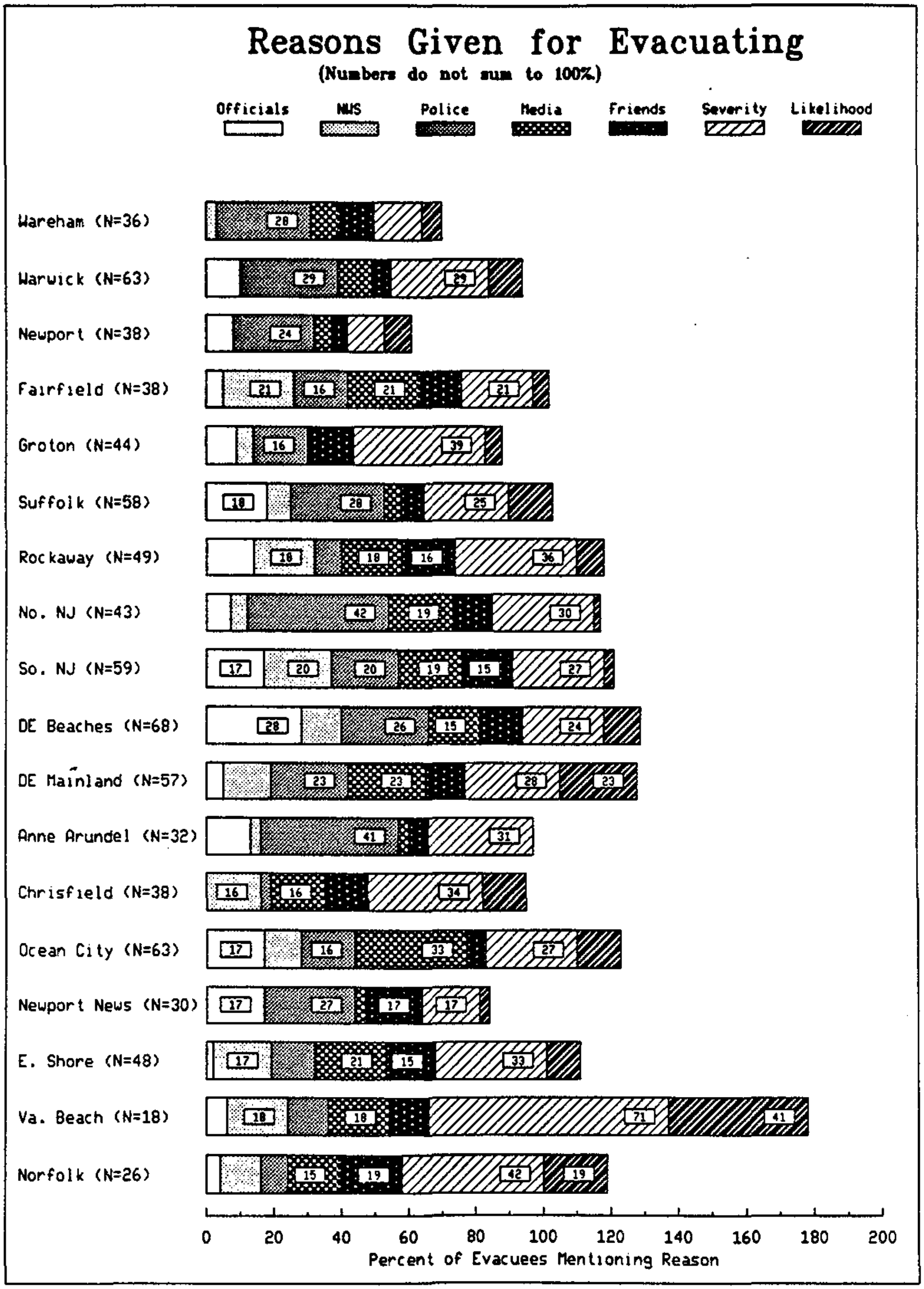

Reasons Given for Evacuating
(Numbers do not sum to 100%)
Officials
NWS
Police
Media
Friends
Severity
Likelihood
Wareham (N=36)
Warwick (N=63)
Newport (N=38)
Fairfield (N=38)
Groton (N=44)
Suffolk (N=58)
Rockaway (N=49)
No. NJ (N=43)
So. NJ (N=59)
DE Beaches (N=68)
DE Mainland (N=57)
Anne Arundel (N=32)
Chrisfield (N=38)
Ocean City (N=63)
Newport News (N=30)
E. Shore (N=48)
Va. Beach (N=18)
Norfolk (N=26)
0 20 40 60 80 100 120 140 160 180 200
Percent of Evacuees Mentioning Reason

FIG. 9

The two sorts of information mentioned concerned either the severity of hurricane Gloria or the likelihood that the storm would strike the respondent's location. Severity was cited more frequently than likelihood of hitting.

Effect of Evacuation Notices

Figure 10 shows the percentage of interviewees who, when asked explicitly, said they that public officials in their area said they should evacuate. Affirmative responses do not necessarily mean that officials actually said the respondents should leave, but the respondents believed that to have been the case. At 7 sites more than 45% said they heard officials say to leave. The beach area of the Delaware sample was highest at 74%. Denton was by far the lowest at 6%. It is no coincidence that the Delaware beach sample also had the highest evacuation rate and Denton the lowest.

Figure 11 illustrates the point even more clearly. In every survey site, people who said they heard evacuation notices from officials were substantially more likely to evacuate than those who said they didn't hear such notices. Only in Delaware and Ocean City, MD were the differences small, but in those instances a high percentage of both groups left. Overall, as indicated by the two sets of bars at the bottom of the graph, people hearing from officials that they were supposed to evacuate were three times as likely to evacuate as others.

Most people saying they heard an official evacuation notice understood the notice to be a recommendation rather than a mandatory order (Fig. 12). Respondents believing they were being ordered to evacuate were much more likely to leave than those who believed the notice was advisory (Fig. 13). In the northern sample 93% "hearing" an order evacuated, as did 84% in the southern area.

The effect of perceived notices and orders in Gloria was exactly the effect observed elsewhere in other hurricanes. If officials want residents to evacuate, they must tell them. But if they tell them, compliance will be good.

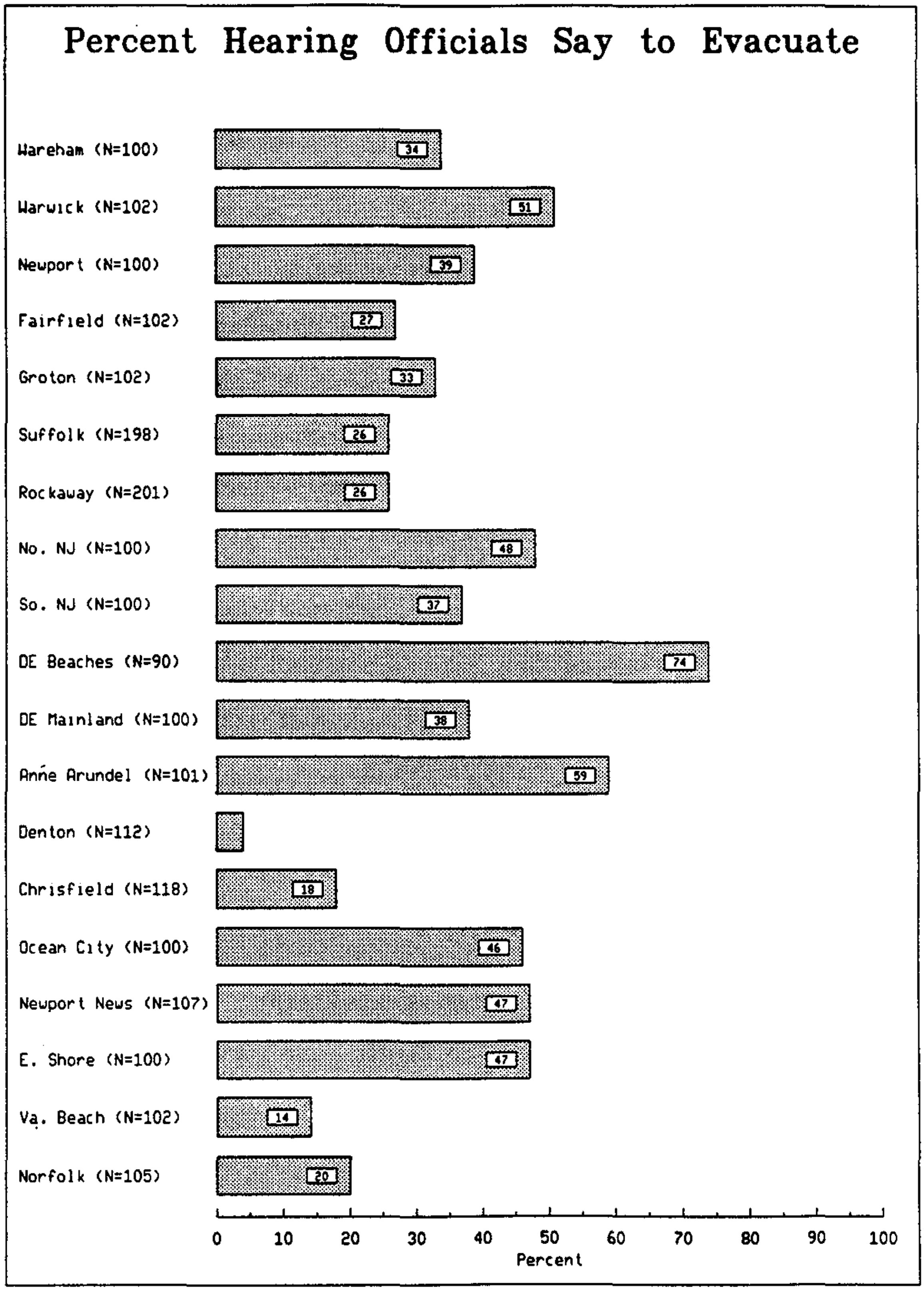
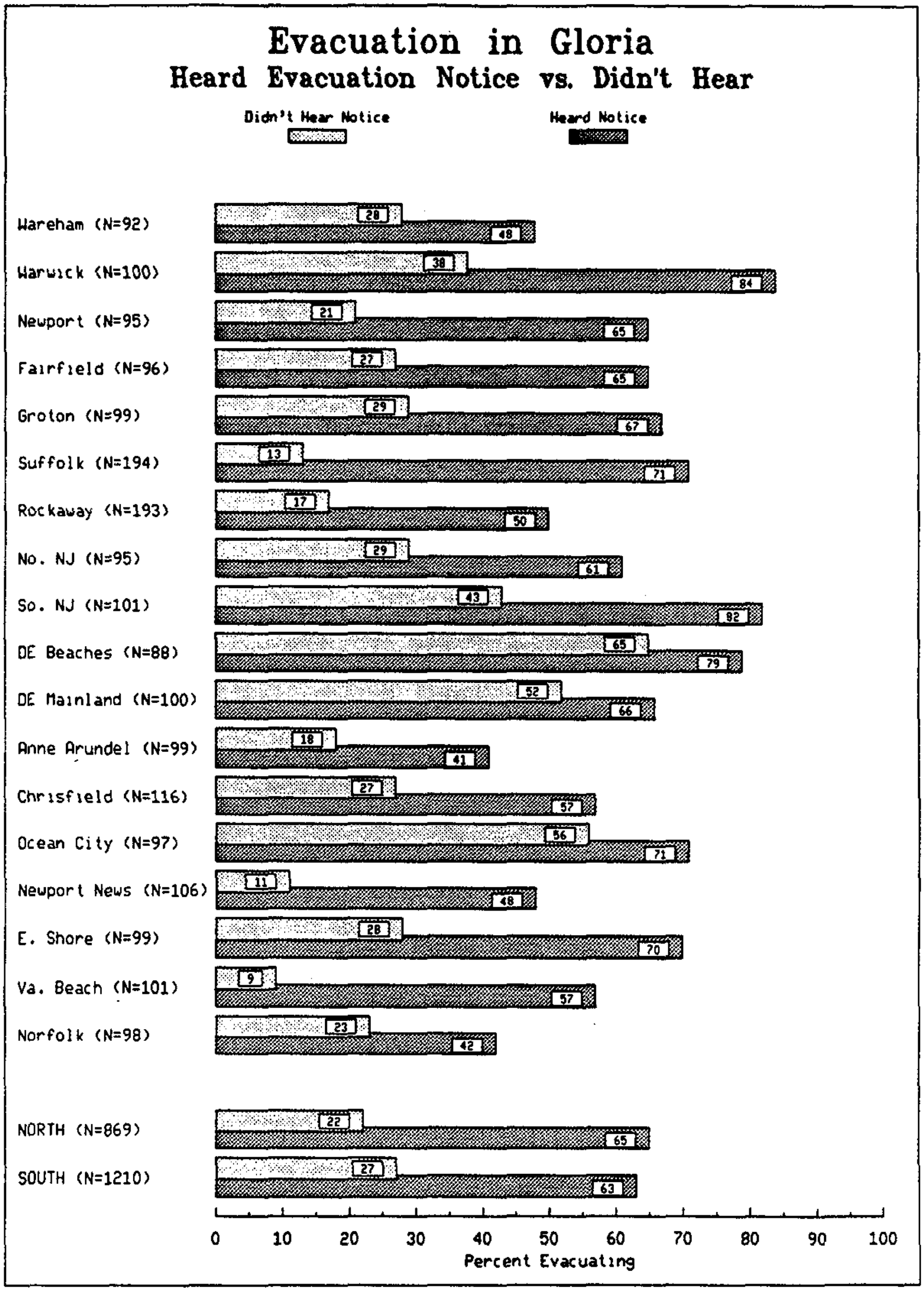

Percent Hearing Officials Say to Evacuate
Wareham (N=100)
Warwick (N=102)
Newport (N=100)
Fairfield (N=102)
Groton (N=102)
Suffolk (N=198)
Rockaway (N=201)
No. NJ (N=100)
So. NJ (N=100)
DE Beaches (N=90)
DE Mainland (N=100)
Anne Arundel (N=101)
Denton (N=112)
Chrisfield (N=118)
Ocean City (N=100)
Newport News (N=107)
E. Shore (N=100)
Va. Beach (N=102)
Norfolk (N=105)
34
51
39
27
33
26
26
48
37
74
38
59
18
46
47
47
14
20
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 10



Evacuation in Gloria
Heard Evacuation Notice vs. Didn't Hear
Didn't Hear Notice
Heard Notice
Wareham (N=92)
28
48
Warwick (N=100)
38
84
Newport (N=95)
21
65
Fairfield (N=96)
27
65
Groton (N=99)
29
67
Suffolk (N=194)
13
71
Rockaway (N=193)
17
50
No. NJ (N=95)
29
61
So. NJ (N=101)
43
82
DE Beaches (N=88)
65
79
DE Mainland (N=100)
52
66
Anne Arundel (N=99)
18
41
Chrisfield (N=116)
27
57
Ocean City (N=97)
56
71
Newport News (N=106)
11
48
E. Shore (N=99)
28
70
Va. Beach (N=101)
9
57
Norfolk (N=98)
23
42
NORTH (N=869)
22
65
SOUTH (N=1210)
27
63
0 10 20 30 40 50 60 70 80 90 100
Percent Evacuating

FIG. 11

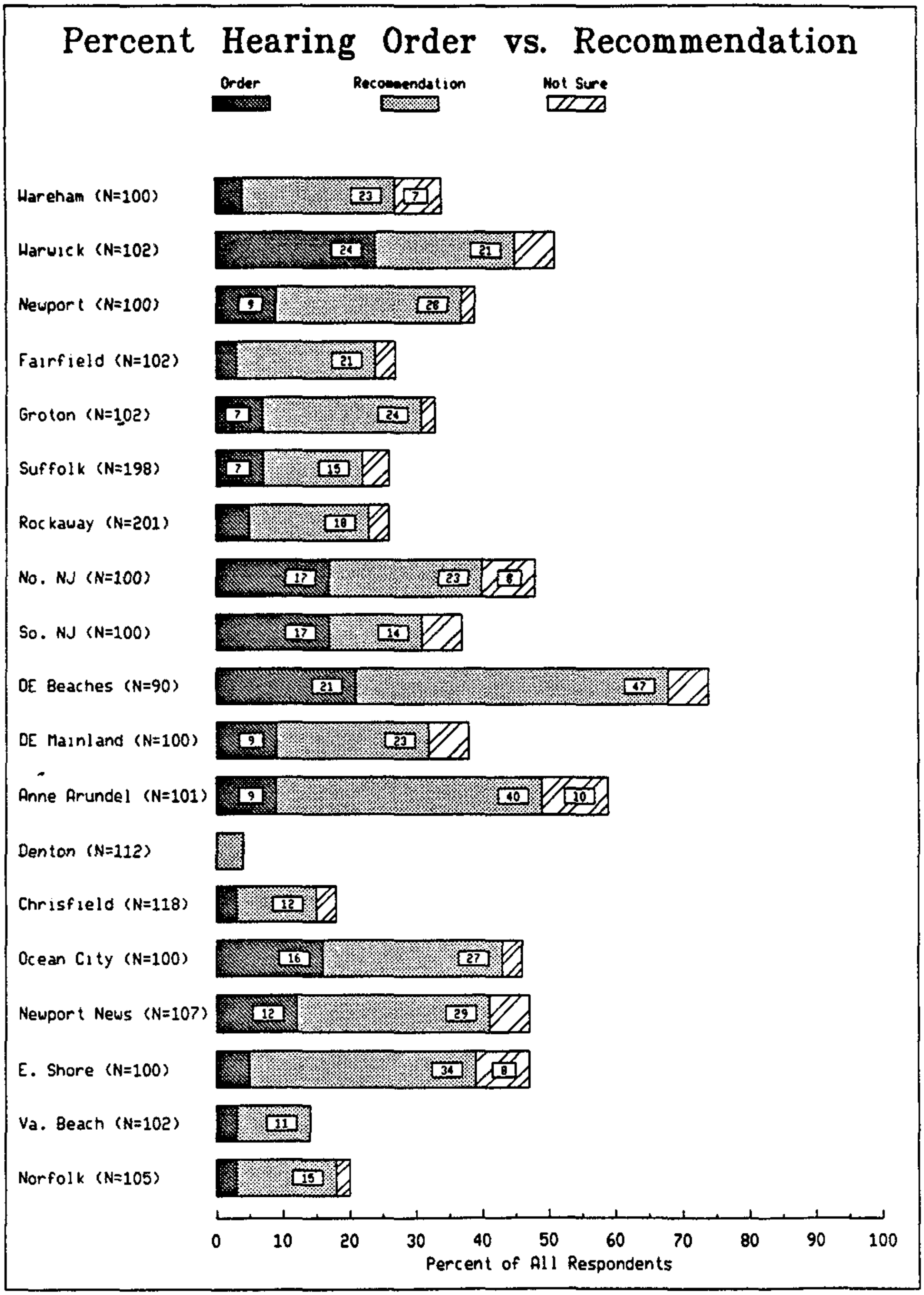
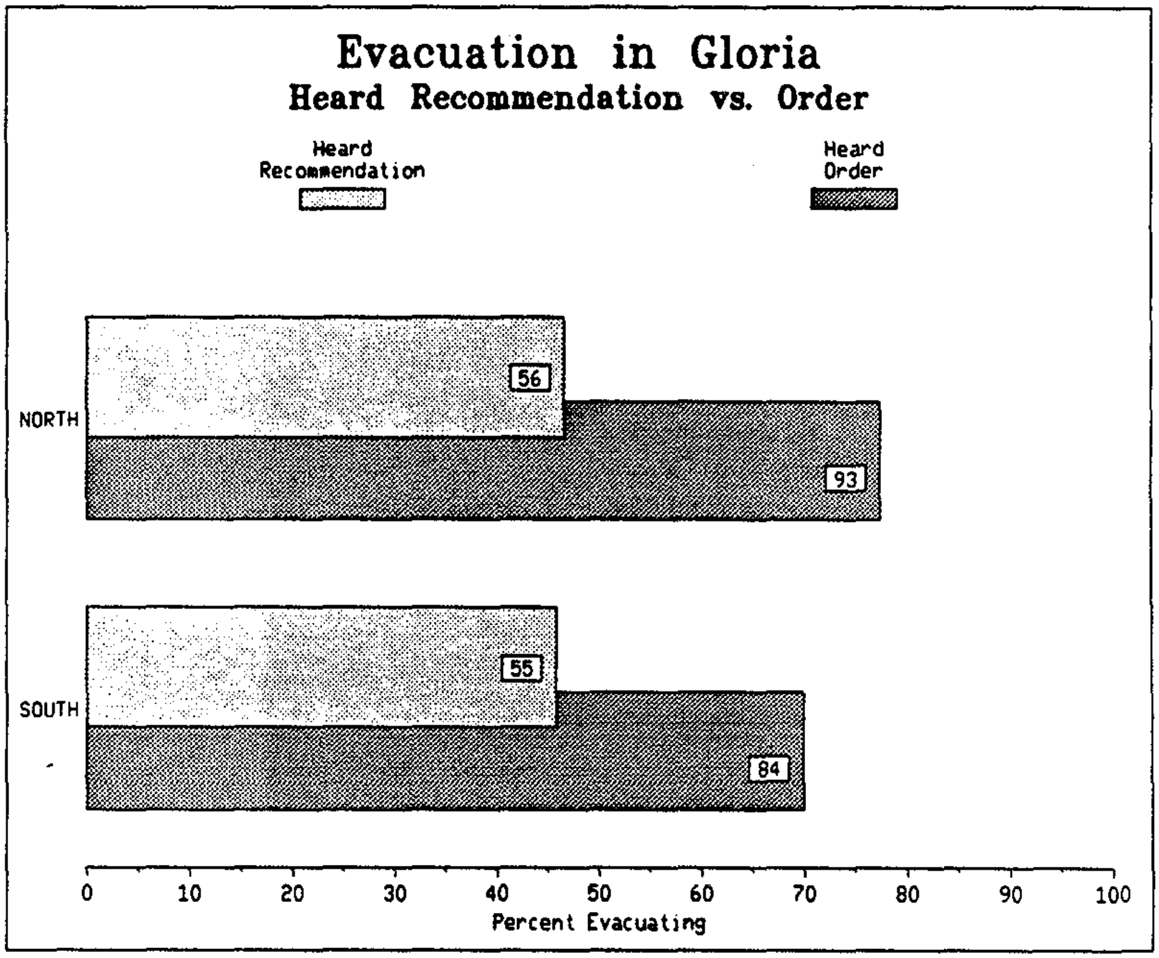

Percent Hearing Order vs. Recommendation
Order
Recommendation
Not Sure
Wareham (N=100)
Warwick (N=102)
Newport (N=100)
Fairfield (N=102)
Groton (N=102)
Suffolk (N=198)
Rockaway (N=201)
No. NJ (N=100)
So. NJ (N=100)
DE Beaches (N=90)
DE Mainland (N=100)
Anne Arundel (N=101)
Denton (N=112)
Chrisfield (N=118)
Ocean City (N=100)
Newport News (N=107)
E. Shore (N=100)
Va. Beach (N=102)
Norfolk (N=105)
23
7
24
21
9
28
21
7
24
7
15
18
17
23
8
17
14
21
47
9
23
9
40
10
12
16
27
12
29
34
8
11
15
0
10
20
30
40
50
60
70
80
90
100
Percent of All Respondents

FIG. 12



Evacuation in Gloria
Heard Recommendation vs. Order
Heard Recommendation
Heard Order
NORTH
56
93
SOUTH
55
84
0
10
20
30
40
50
60
70
80
90
100
Percent Evacuating

FIG. 13

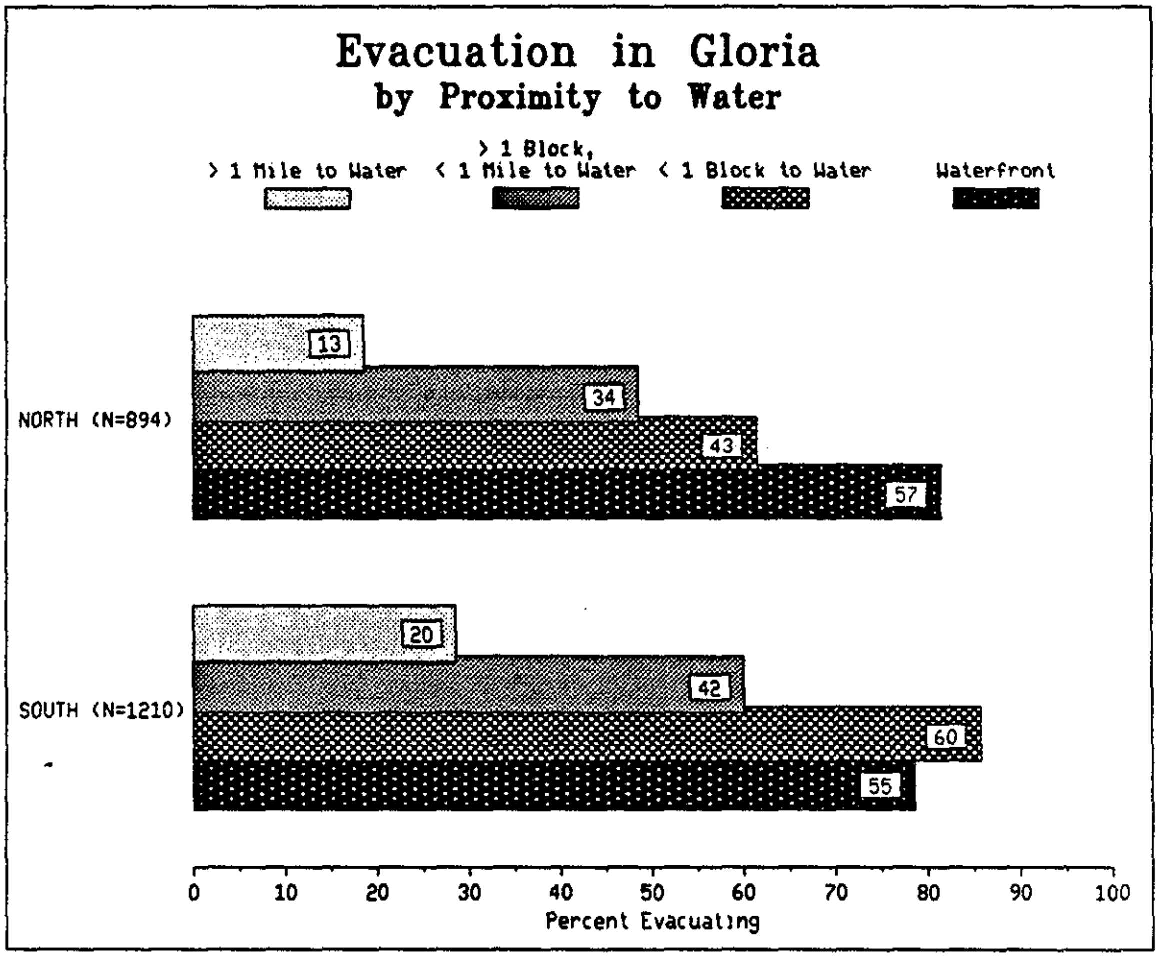
It is also important that roughly 25% of the people not hearing official evacuation notices also left. The "shadow" evacuation phenomenon, whereby more people leave than actually need to, is common.

Effect of Perceived Safety

Proximity to water is not a perfect surrogate for hazardousness of a dwelling because elevation might rise quickly only a short distance from the shore or flooding might extend miles inland. In general, though, people who lived closer to the water were more likely to evacuate than other people (Fig. 14). The only confusion in the trend was in the southern sample where people living within a block of water appeared slightly more likely to evacuate than waterfront residents.

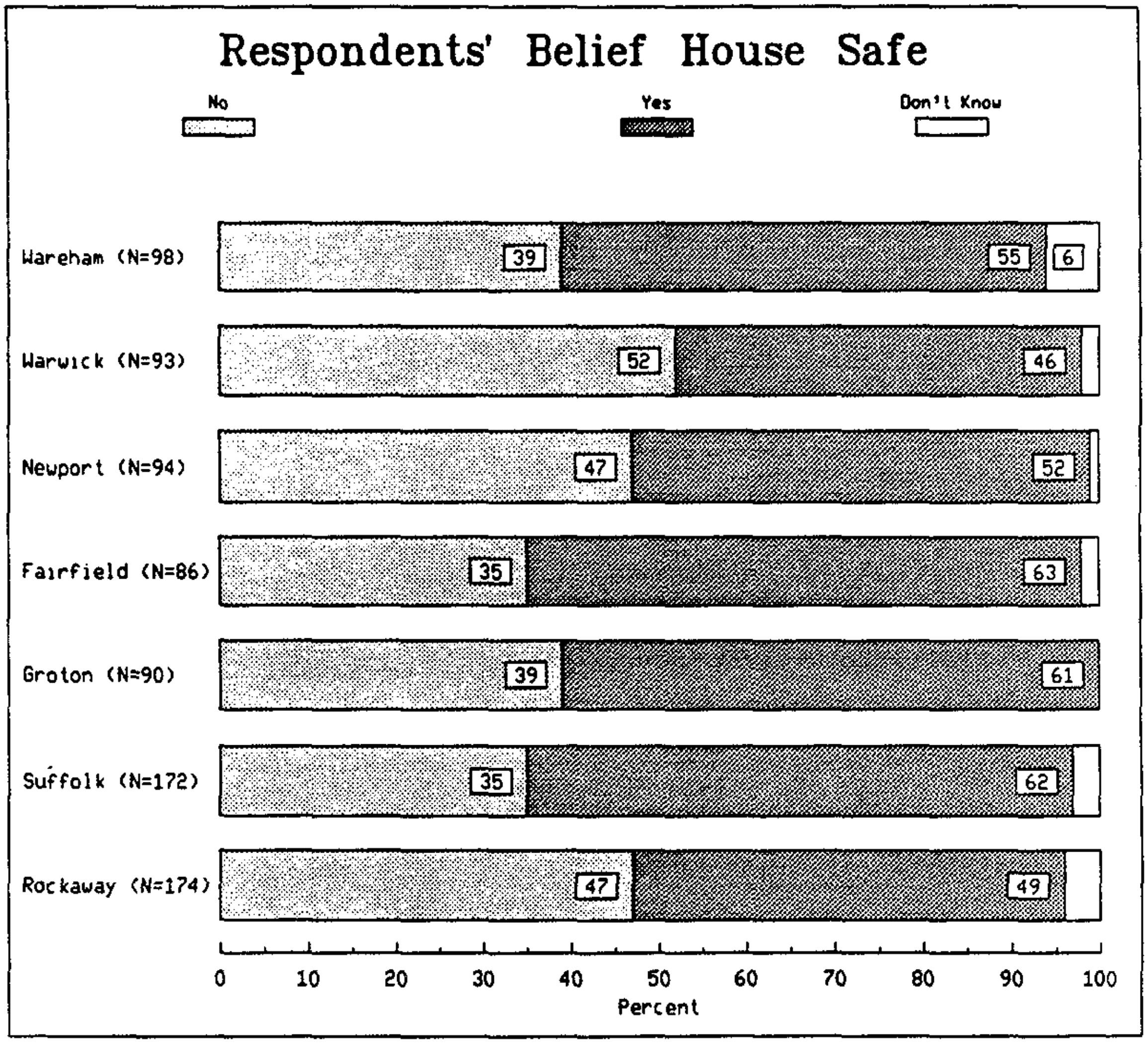
This pattern is common in hurricane evacuations and predicted by the general response model. Officials are more likely to tell people in more hazardous locations to evacuate, but residents of those areas are also more aware of the risk they take in staying.

Interviewees in the northern sample were asked whether they felt their house would be safe in a hurricane. A majority in all sites except Warwick felt their home would be safe, but in all locations a substantial minority considered their dwellings unsafe (Fig. 15). People believing their house was unsafe were more than twice as likely to evacuate as others (Fig. 16). The fact that only about half those saying their home would be unsafe evacuated in Gloria attests to the fact that more than belief that one's dwelling is dangerous is necessary to compel people to evacuate. Figure 17 depicts the association between belief one's house is safe (unsafe) and proximity to water.



Evacuation in Gloria
by Proximity to Water
> 1 Mile to Water
> 1 Block,
< 1 Mile to Water
< 1 Block to Water
Waterfront
NORTH (N=894)
13
34
43
57
SOUTH (N=1210)
20
42
60
55
0
10
20
30
40
50
60
70
80
90
100
Percent Evacuating

FIG. 14



Respondents' Belief House Safe
No
Yes
Don't Know
Wareham (N=98)
39
55
6
Warwick (N=93)
52
46
Newport (N=94)
47
52
Fairfield (N=86)
35
63
Groton (N=90)
39
61
Suffolk (N=172)
35
62
Rockaway (N=174)
47
49
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 15

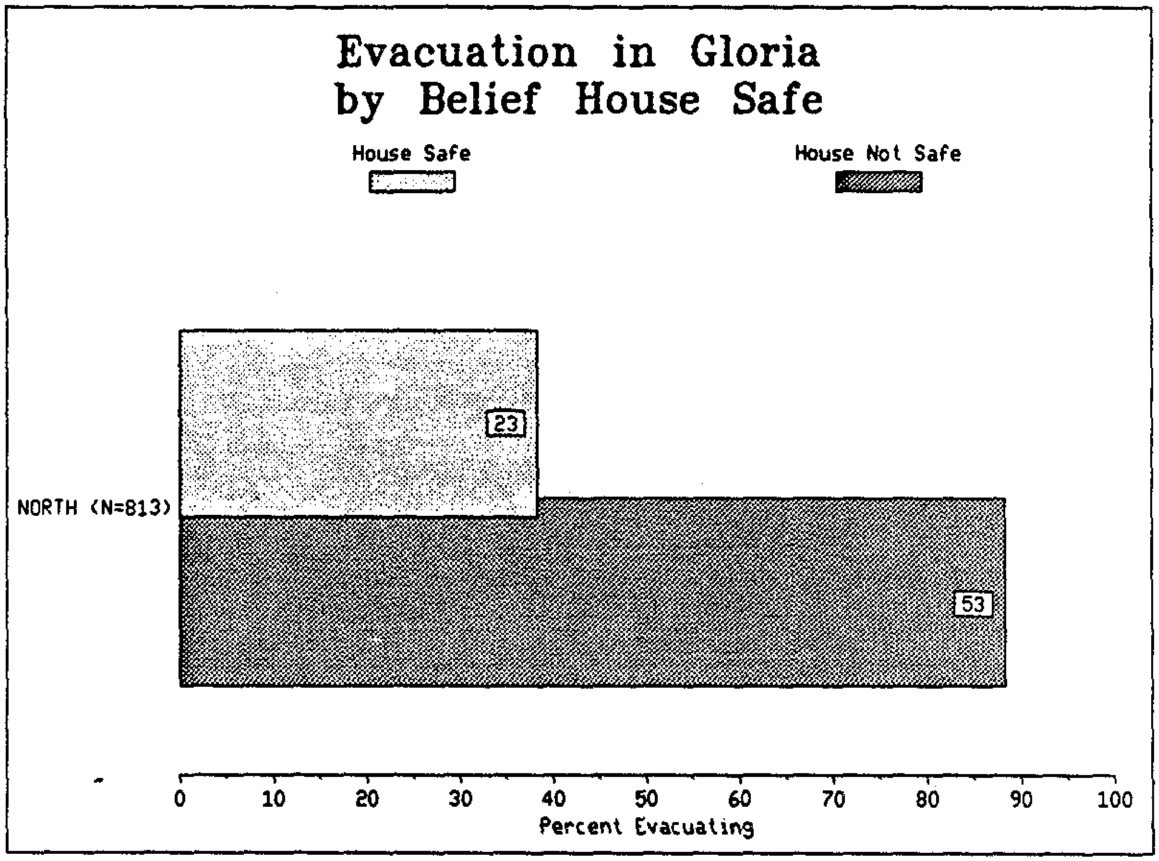
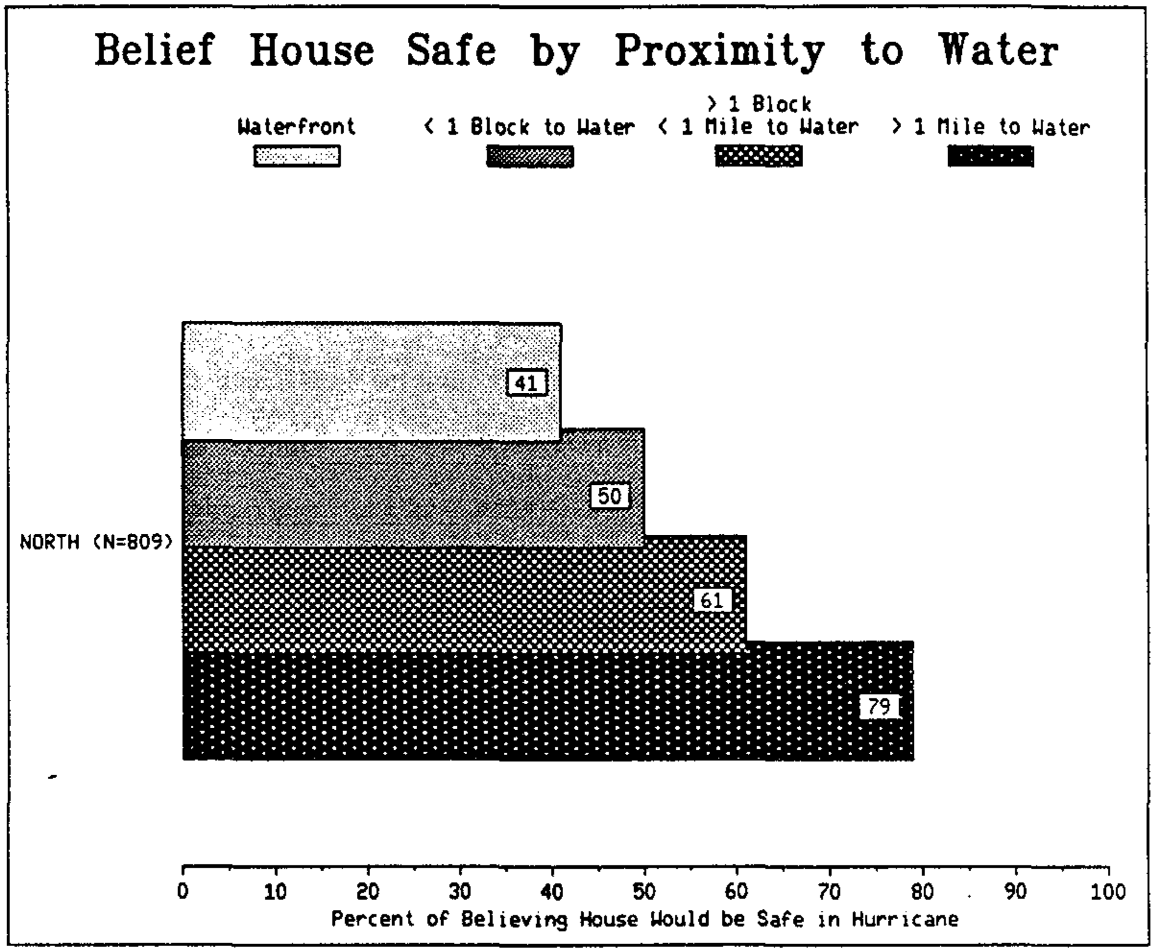

Evacuation in Gloria
by Belief House Safe
House Safe
House Not Safe
23
NORTH (N=813)
53
0
10
20
30
40
50
60
70
80
90
100
Percent Evacuating

FIG. 16



Belief House Safe by Proximity to Water
Waterfront
< 1 Block to Water
> 1 Block
< 1 Mile to Water
> 1 Mile to Water
NORTH (N=809)
41
50
61
79
0
10
20
30
40
50
60
70
80
90
100
Percent of Believing House Would be Safe in Hurricane

FIG. 17

Reasons Given for Not Evacuating

The most common reason given for not evacuating in Gloria was that respondents felt safe staying where they were -- either they didn't believe the storm was severe enough to threaten their dwelling or the storm wouldn't strike their area (Fig. 18). A variety of other reasons were also volunteered.

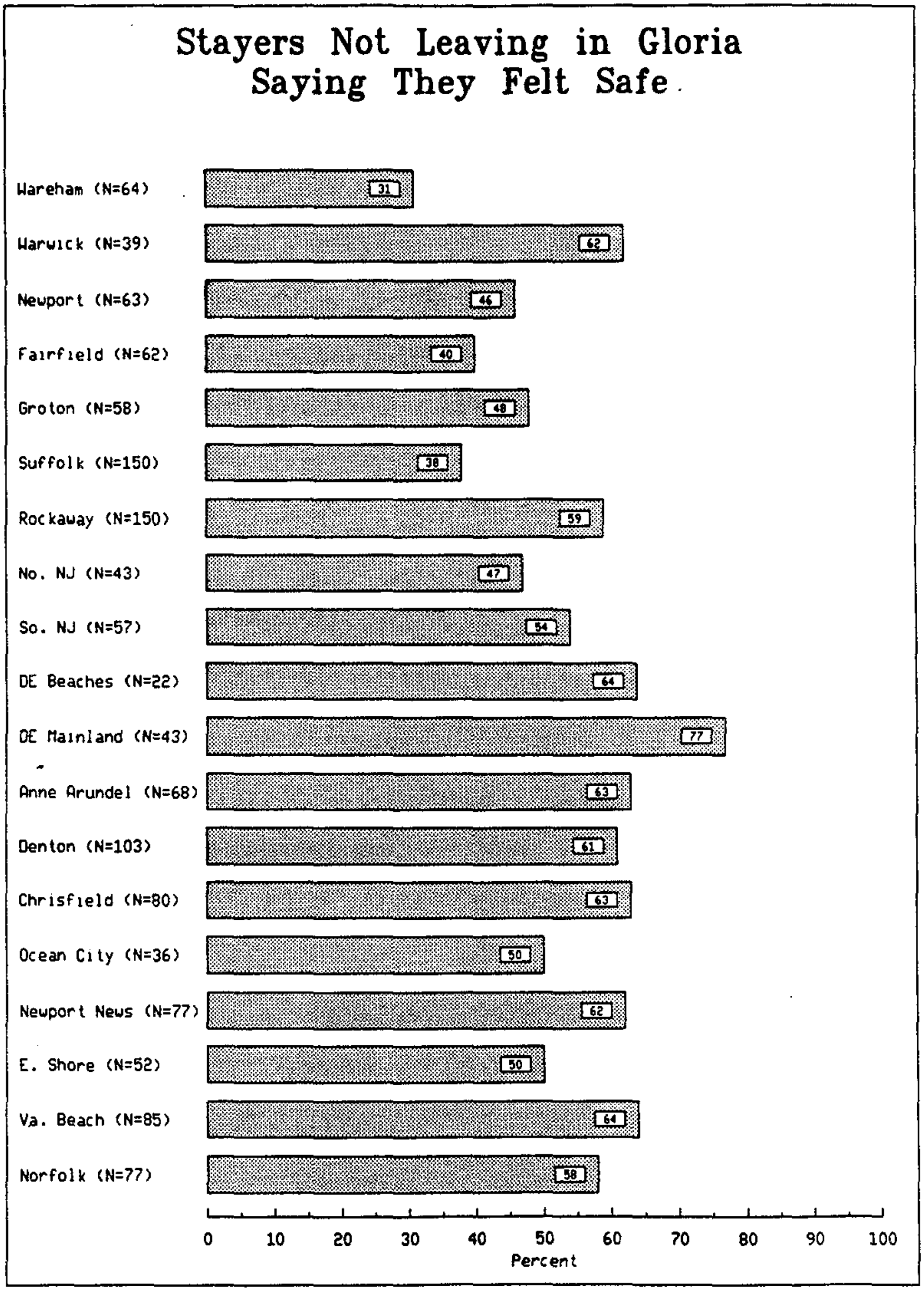
Reasons attributing the decision to not evacuate to specific types or sources of information are graphed in Figure 19. As many as 19% (in Denton) said they stayed because officials didn't tell them to leave. Many respondents said they stayed for reasons having nothing to do with safety or information (Fig. 20). In only three survey locations (Rockaway, Denton, and Ocean City, MD) did anyone say they failed to evacuate because they had no transportation. A number in most places, however, said they stayed because they had no place to go.

There are no clear differences in reasons given across the region as a whole to distinguish the area from other locations in other hurricane threats.

Other Predictors and Non-predictors

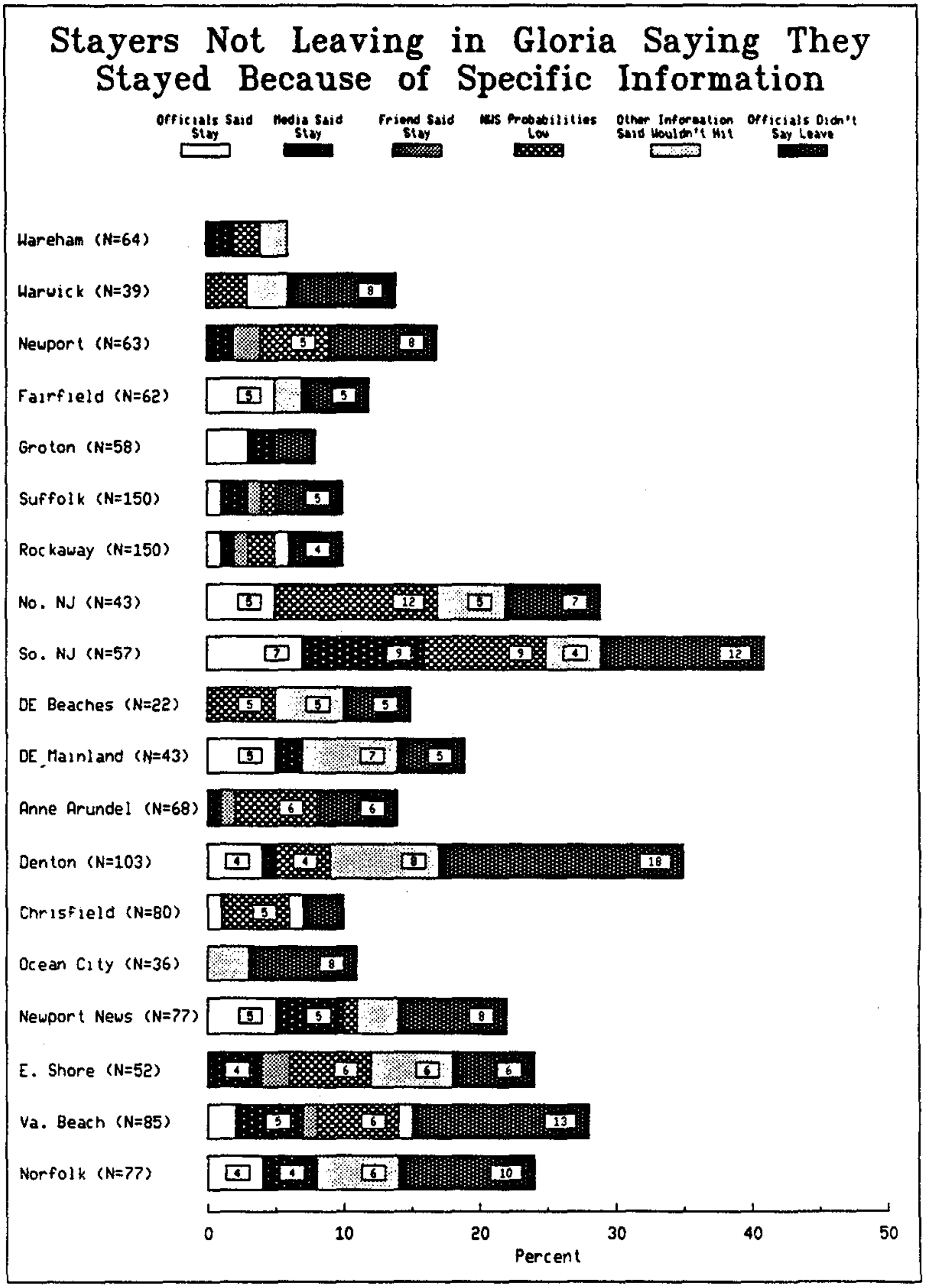
Housing varied too little to test for response differences in all but two locations. Thirty-nine percent of the Rockaway sample contained high-rise residents, and only 8% of them evacuated, compared to 40% of single-family homes. In the Delaware mainland sample 45% of the dwellings were mobile homes, 75% of which were evacuated, whereas only 35% of other housing was evacuated. The mobile home finding is common, but there has been little comparative evidence elsewhere concerning high-rise dwellings.

Neither income nor age were associated with whether people evacuated. Income is seldom found to predict evacuation in other parts of the nation. Age is usually a factor only in areas where there are a large number of retirees such as south Florida.



Stayers Not Leaving in Gloria
Saying They Felt Safe
Wareham (N=64)
31
Warwick (N=39)
62
Newport (N=63)
46
Fairfield (N=62)
40
Groton (N=58)
48
Suffolk (N=150)
38
Rockaway (N=150)
59
No. NJ (N=43)
47
So. NJ (N=57)
54
DE Beaches (N=22)
64
DE Mainland (N=43)
77
Anne Arundel (N=68)
63
Denton (N=103)
61
Chrisfield (N=80)
63
Ocean City (N=36)
50
Newport News (N=77)
62
E. Shore (N=52)
50
Va. Beach (N=85)
64
Norfolk (N=77)
58
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 18



Stayers Not Leaving in Gloria Saying They Stayed Because of Specific Information
Officials Said Stay
Media Said Stay
Friend Said Stay
NWS Probabilities Low
Other Information Said Wouldn't Hit
Officials Didn't Say Leave
Wareham (N=64)
Warwick (N=39)
Newport (N=63)
Fairfield (N=62)
Groton (N=58)
Suffolk (N=150)
Rockaway (N=150)
No. NJ (N=43)
So. NJ (N=57)
DE Beaches (N=22)
DE Mainland (N=43)
Anne Arundel (N=68)
Denton (N=103)
Chrisfield (N=80)
Ocean City (N=36)
Newport News (N=77)
E. Shore (N=52)
Va. Beach (N=85)
Norfolk (N=77)
0
10
20
30
40
50
Percent

FIG. 19

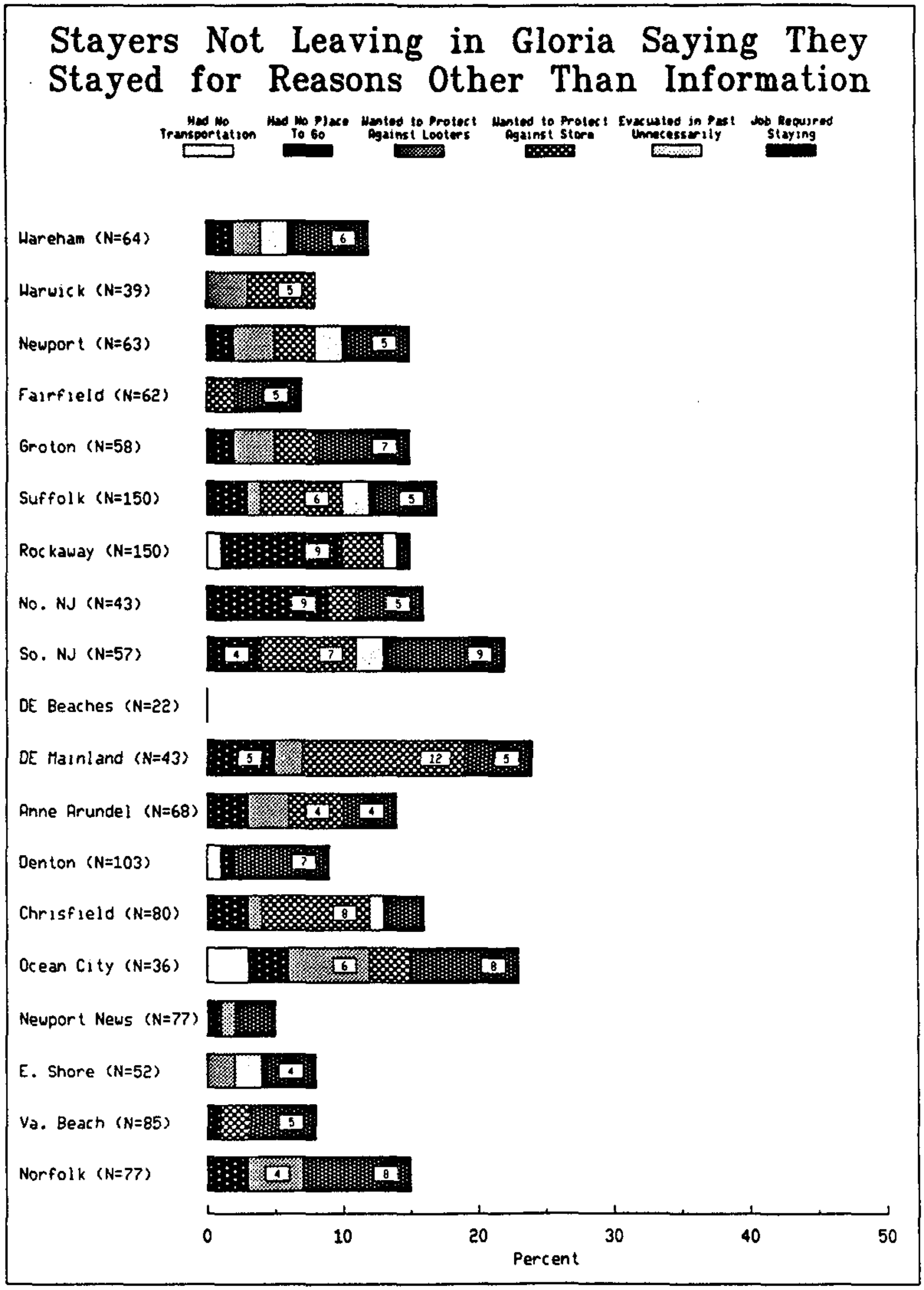
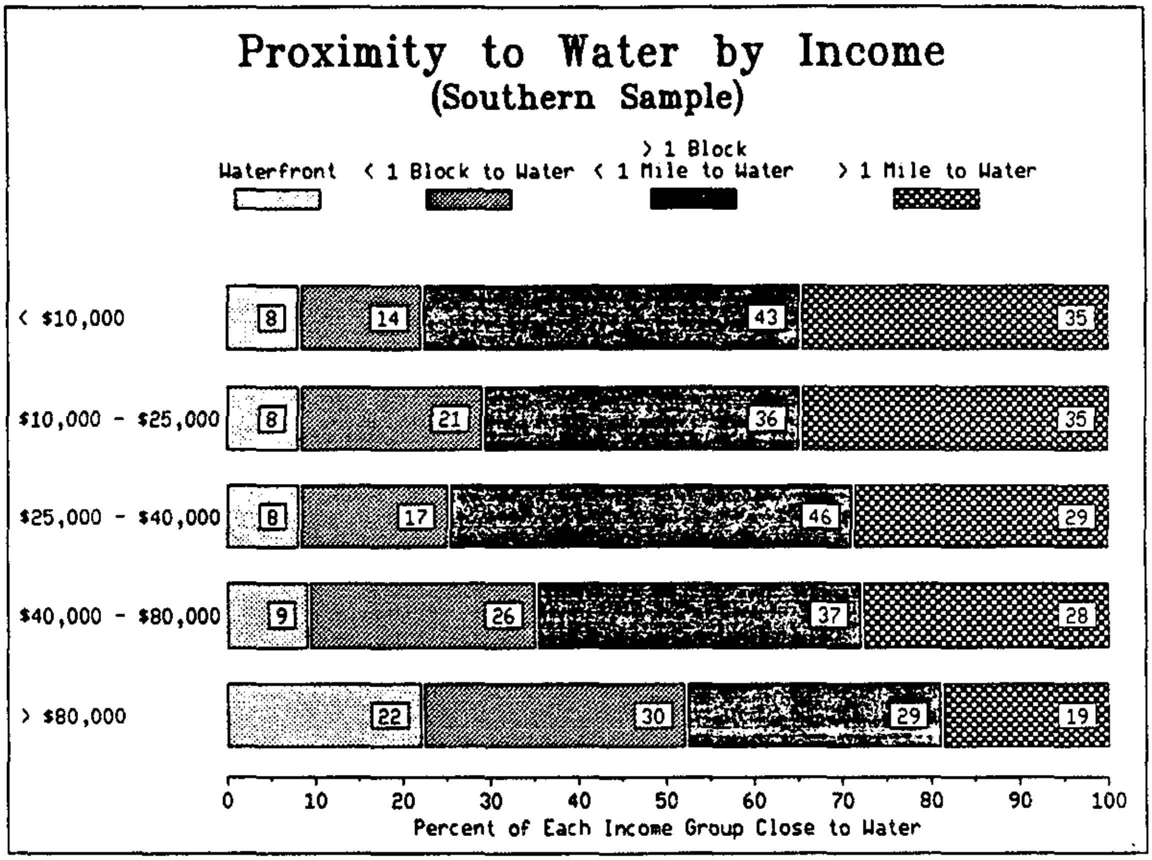

Stayers Not Leaving in Gloria Saying They Stayed for Reasons Other Than Information
Had No Transportation
Had No Place To Go
Wanted to Protect Against Looters
Wanted to Protect Against Storm
Evacuated in Past Unnecessarily
Job Required Staying
Wareham (N=64)
Warwick (N=39)
Newport (N=63)
Fairfield (N=62)
Groton (N=58)
Suffolk (N=150)
Rockaway (N=150)
No. NJ (N=43)
So. NJ (N=57)
DE Beaches (N=22)
DE Mainland (N=43)
Anne Arundel (N=68)
Denton (N=103)
Chrisfield (N=80)
Ocean City (N=36)
Newport News (N=77)
E. Shore (N=52)
Va. Beach (N=85)
Norfolk (N=77)
0
10
20
30
40
50
Percent

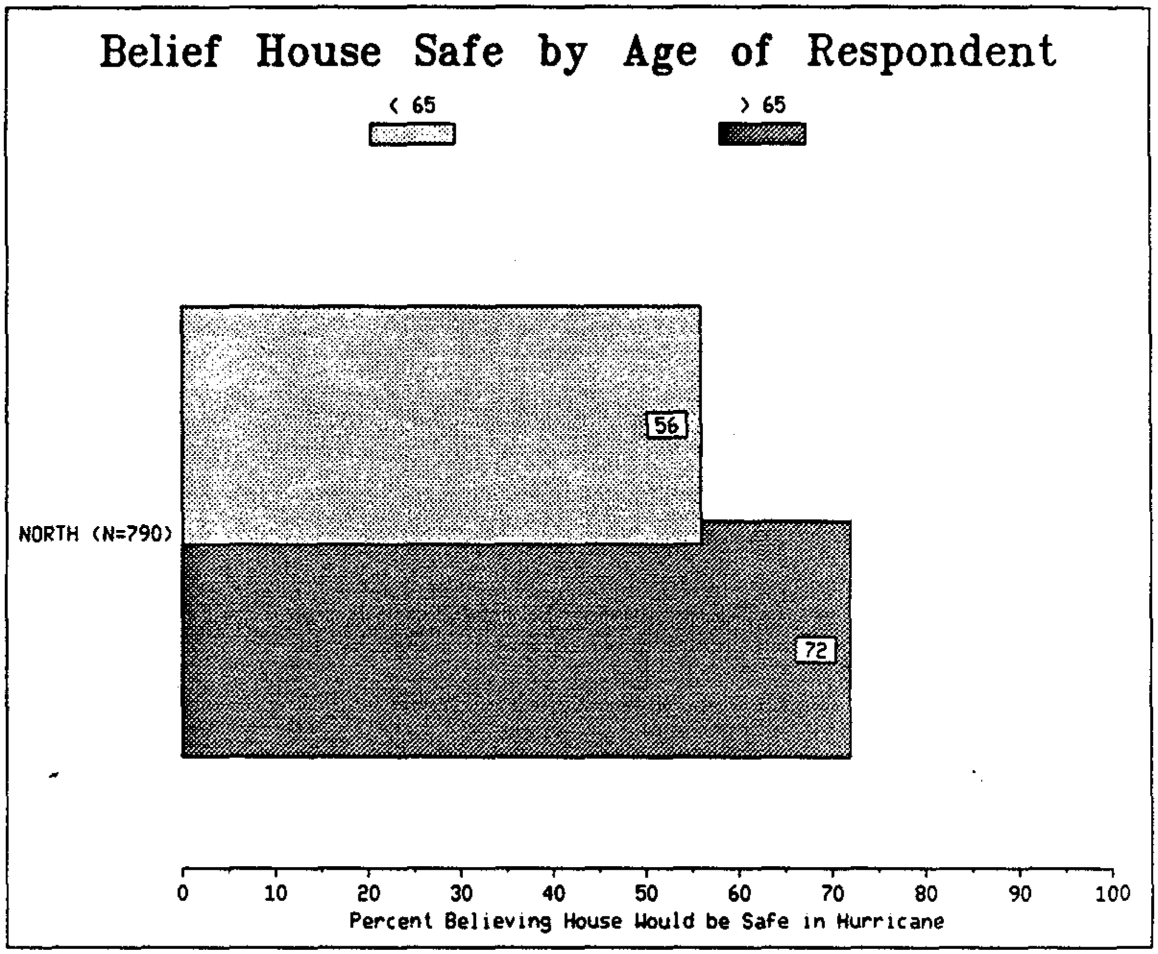
FIG. 20

In the northern area income was not correlated at all with proximity to water, and in the southern area, the association wasn't strong (Figure 21). In neither area was age related to water proximity. Elderly residents were slightly more likely to say their house would be safe in a hurricane than other respondents (Fig. 22).



Proximity to Water by Income
(Southern Sample)
Waterfront
< 1 Block to Water
> 1 Block < 1 Mile to Water
> 1 Mile to Water
< $10,000
$10,000 - $25,000
$25,000 - $40,000
$40,000 - $80,000
> $80,000
8
14
43
35
8
21
36
35
8
17
46
29
9
26
37
28
22
30
29
19
0
10
20
30
40
50
60
70
80
90
100
Percent of Each Income Group Close to Water

FIG. 21



Belief House Safe by Age of Respondent
< 65
> 65
56
72
NORTH (N=790)
0
10
20
30
40
50
60
70
80
90
100
Percent Believing House Would be Safe in Hurricane

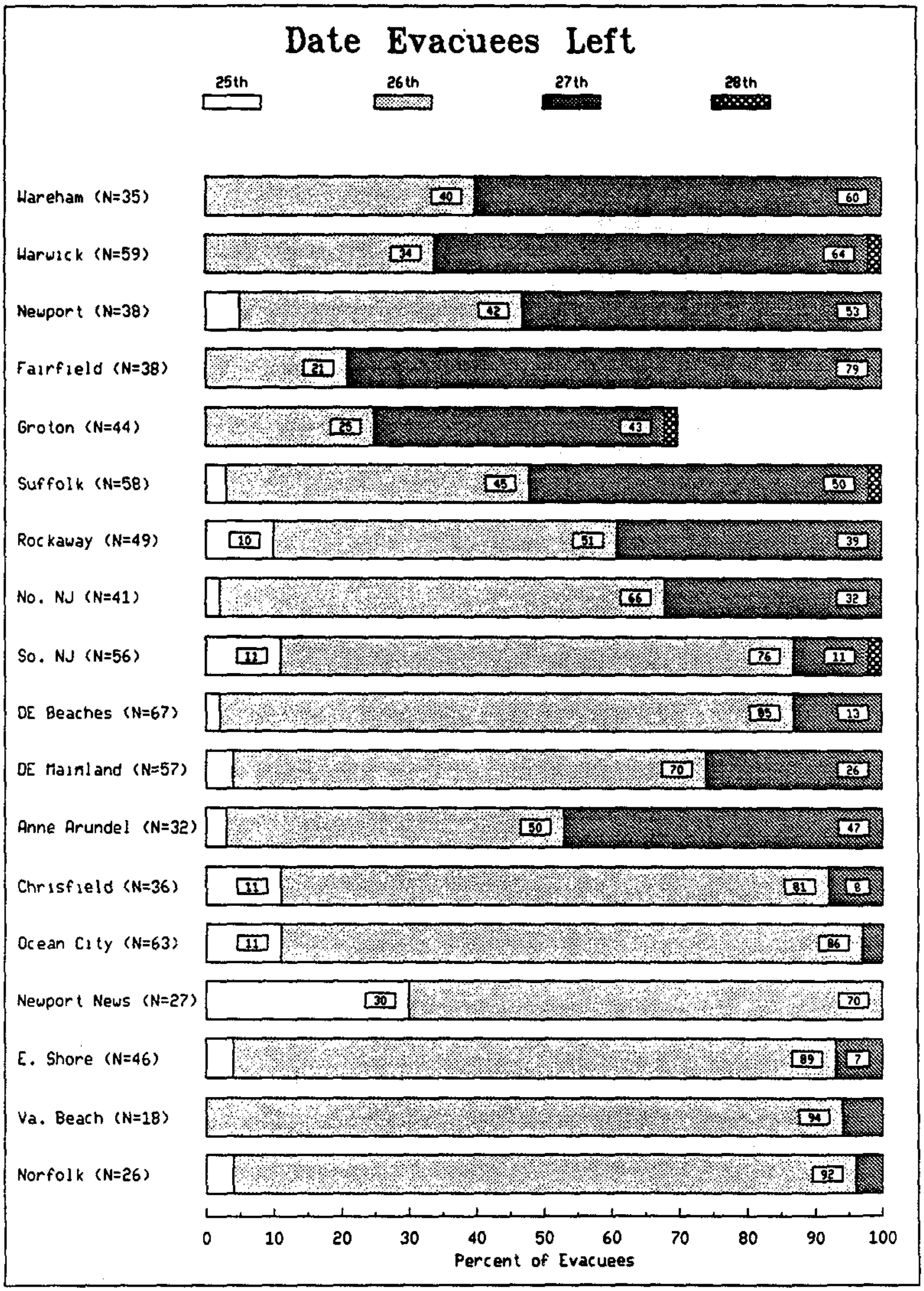
FIG. 22

Evacuation Timing

Evacuation timing is concerned with how many of the eventual evacuees leave at various times after (or before) being told to evacuate or relative to the arrival of a hurricane. Figure 23 shows the date on which Gloria evacuees said they evacuated. Clearly and understandably, people left earlier in the southern area than in the northern. This was undoubtedly a consequence of the fact that the storm threatened southern sites earlier and officials told people earlier to leave.

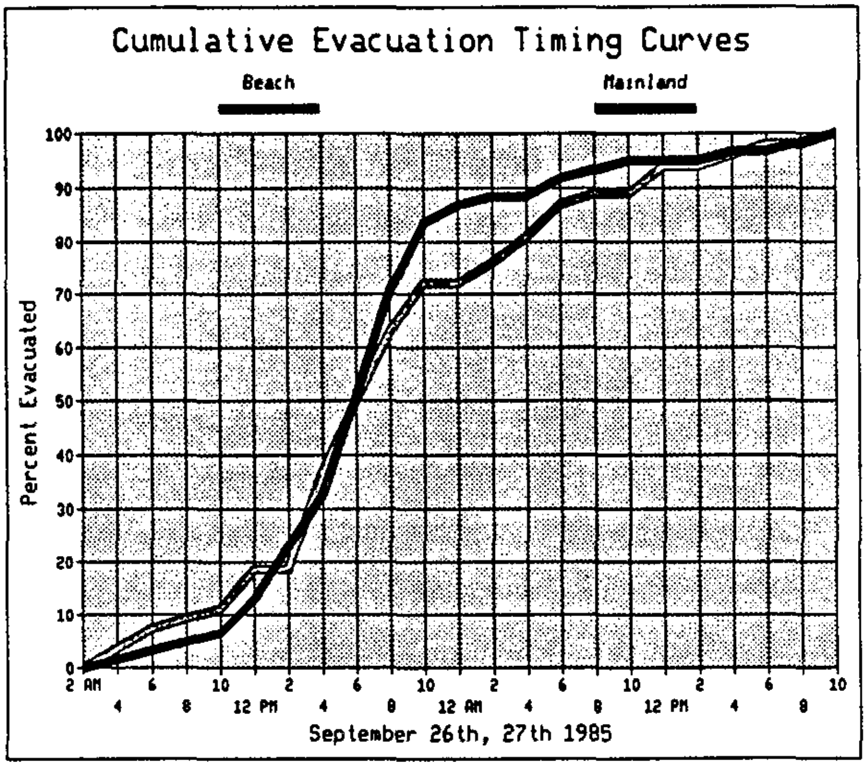
Evacuees were also asked what time of day they left. Plotting that data yields a cumulative evacuation curve like the ones in Figure 24 for the two Delaware survey locations. In this particular case, such curves could be misleading, however. Respondents are being asked to recall the time of day they did something two years earlier, and recall might not be good enough to place great confidence in such specific information. Even if people could remember accurately, the sample sizes make the exact shape of the plotted curves suspect.

These considerations present no difficulty in deriving planning assumptions for the region, however. Other evidence has already shown that most people didn't evacuate in Gloria without being told to do so by officials. The timing of evacuation notices, therefore, will be the primary determinant of evacuation timing, just as it is in other locations. Just how promptly people will leave after being told can't be generalized from a single evacuation in any case. People will leave as promptly or as leisurely as they believe they must, based upon information available during a particular threat. Planning recommendations, therefore, will contain three different response timing curves, each fitting a set of circumstances which are plausible at each study location.



Date Evacuees Left
25th
26th
27th
28th
Wareham (N=35)
Warwick (N=59)
Newport (N=38)
Fairfield (N=38)
Groton (N=44)
Suffolk (N=58)
Rockaway (N=49)
No. NJ (N=41)
So. NJ (N=56)
DE Beaches (N=67)
DE Mainland (N=57)
Anne Arundel (N=32)
Chrisfield (N=36)
Ocean City (N=63)
Newport News (N=27)
E. Shore (N=46)
Va. Beach (N=18)
Norfolk (N=26)
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuees

FIG. 23



Cumulative Evacuation Timing Curves
Beach
Mainland
100
90
80
70
60
50
40
30
20
10
0
Percent Evacuated
2 AM
4
6
8
10
12 PM
2
4
6
8
10
12 AM
2
4
6
8
10
12 PM
2
4
6
8
10
September 26th, 27th 1985

FIG. 24

Types of Refuge Used

Response in Gloria

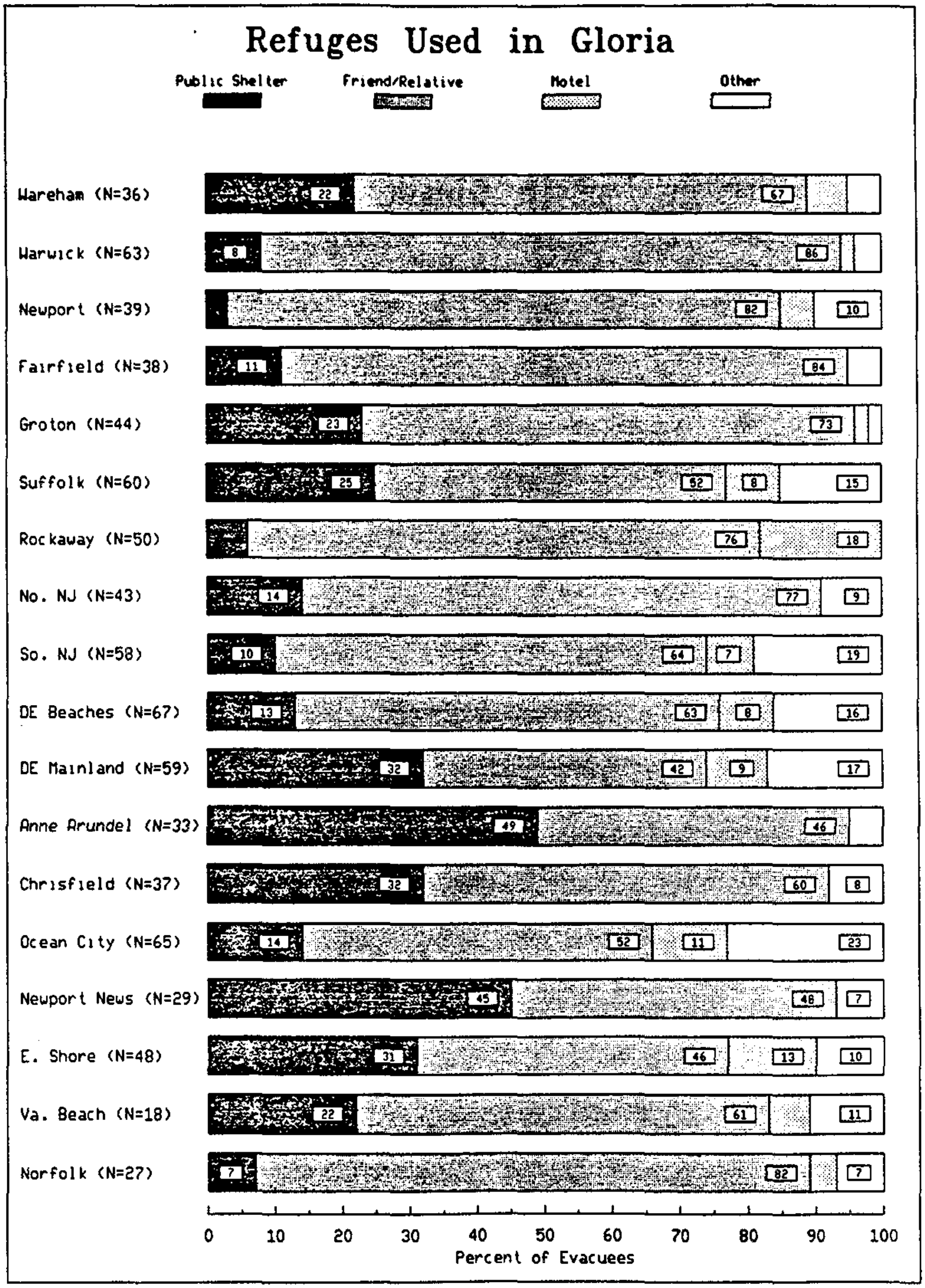
Figure 25 indicates the types of refuge used by evacuees in Gloria. Bear in mind that in most of the samples fewer than 50 people evacuated, yielding only marginally reliable data on this variable. (A sample of 50 will yield data accurate within 10 percentage points of the population value 90% of the time.)

In all but five survey sites a fourth or fewer of all evacuees went to public shelters, but there was widespread variation from site to site. Anne Arundel and Newport News had the highest shelter use rates, at 49% and 45% respectively, but both also had relatively few total evacuees (33 and 29). Newport, RI had the lowest use of public shelters, but Warwick, Rockaway, southern New Jersey, and Norfolk also had very low shelter use rates. Very few people evacuating out of their own town went to public shelters, but more did so in the southern sample than in the northern (Figure 26).

The "other" category was large in some locations. The most common of these responses was going to a second home the respondent owned, their place of work, or to a church not being operated as a Red Cross shelter.

(Non)Predictors of Shelter Use

Common predictors of public shelter use were not verified in the Gloria data. It is unclear whether the region is different, Gloria was different, or idiosyncrasies of the data set simply make verification impossible.



Refuges Used in Gloria
Public Shelter
Friend/Relative
Motel
Other
Wareham (N=36)
Warwick (N=63)
Newport (N=39)
Fairfield (N=38)
Groton (N=44)
Suffolk (N=60)
Rockaway (N=50)
No. NJ (N=43)
So. NJ (N=58)
DE Beaches (N=67)
DE Mainland (N=59)
Anne Arundel (N=33)
Chrisfield (N=37)
Ocean City (N=65)
Newport News (N=29)
E. Shore (N=48)
Va. Beach (N=18)
Norfolk (N=27)
22
67
8
86
82
10
11
84
23
73
25
52
8
15
76
18
14
77
9
10
64
7
19
13
63
8
16
32
42
9
17
49
46
32
60
8
14
52
11
23
45
48
7
31
46
13
10
22
61
11
7
82
7
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuees

FIG. 25

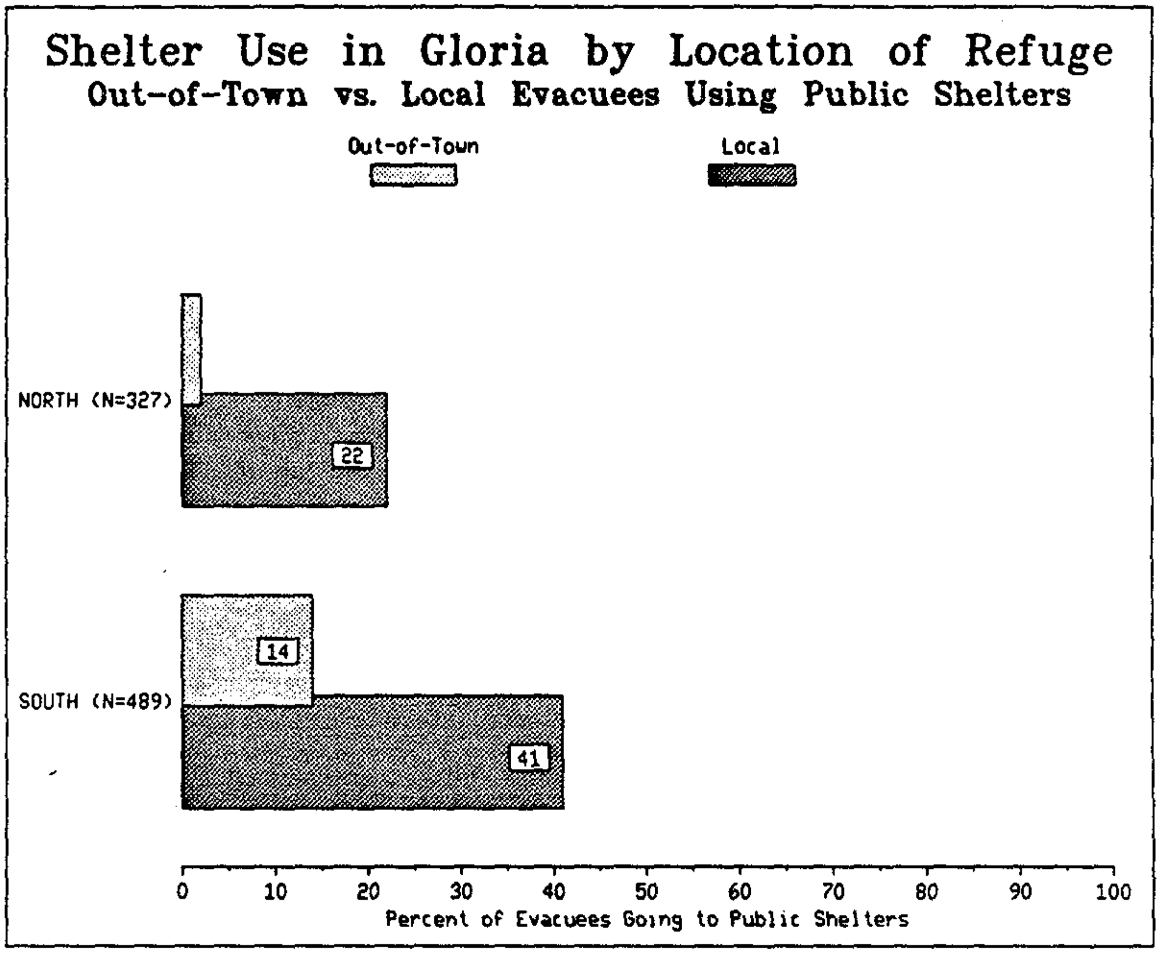

Shelter Use in Gloria by Location of Refuge
Out-of-Town vs. Local Evacuees Using Public Shelters
Out-of-Town
Local
NORTH (N=327)
22
SOUTH (N=489)
14
41
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuees Going to Public Shelters

FIG. 26

For example, income is normally associated with shelter use: low income evacuees are usually more likely to go to public shelters than more affluent evacuees. There is some evidence to support the notion in the Gloria data. Newport News and Chrisfield, with the highest incidence of low income residents in the samples, had two of the highest rates of public shelter use. Anne Arundel, however, with the highest shelter use rate, also had the lowest percentage of surveyed households reporting incomes below $10,000/yr.

Because of the small number of evacuees and even smaller number of public shelter users at each interview location it was not possible to test reliably for associations between income and shelter use in each location. When the samples were aggregated into northern and southern areas to increase sample sizes, no relationship was found between income and shelter use. Aggregating samples, however, can sometimes obscure relationships which exist at lower levels, and that could be occurring in this case. For example, actions by local officials can either encourage or discourage shelter use at the local level. As such actions undoubtedly varied from site to site in Gloria, lumping all the sites together would tend to make it more difficult to detect the effect of other factors such as income. There is also the larger question of whether respondents were candid about their actual incomes and whether the refusal of many people to answer that question might have affected these tests.

Another common predictor of shelter use is hazardousness of one's location. Evacuees from dangerous places such as barrier islands are less likely to use public shelters than evacuees from low-risk areas. Again, there is evidence of this at one scale in the Gloria data: Evacuees from the Delaware beach sample were much less likely to use public shelters than Delaware mainland evacuees. Other beach sample areas such as Ocean City, MD, and the New Jersey samples had some of the lowest shelter use rates.

Sample sizes were too small in individual survey sites to test whether people living farther from water bodies were more likely to use public shelters. When the data was aggregated into northern and southern areas, no relationship was found.

Age is not usually associate with shelter use except in retirement areas, and this proved also to be the case in Gloria.

Hypothetical Refuge Use

Respondents who didn't evacuate in Gloria were asked what sort of refuge they would have sought if they had evacuated. As indicated in Figure 27, hypothetical shelter use was much higher than actual use in most locations. An initial interpretation might be to infer that the people who didn't evacuate in Gloria were actually more prone to use public shelters than those who did evacuate. This relationship between hypothetical and actual shelter use is common, however, and the very same individuals who say they would use public shelters are actually about half as likely to as they themselves believe. Figure 28 compares intended and actual shelter use in a number of locations and storms.

In some surveys people who said they would use public shelters were then asked whether they had friends or relatives in safe locations with whom they could stay if necessary. Most answered affirmatively. Those were then asked whether they might not actually stay with those friends and relatives rather than going to a public shelter. Again, most answered affirmatively, indicating the tenuousness and instability of the hypothetical response.

One reason that actual shelter use tends to be lower than hypothetical is that during hurricane threats, people tend to contact one another, with residents in safe locations often inviting and even urging friends and relatives to come to their houses. Thus options become available that might not have been assumed during a

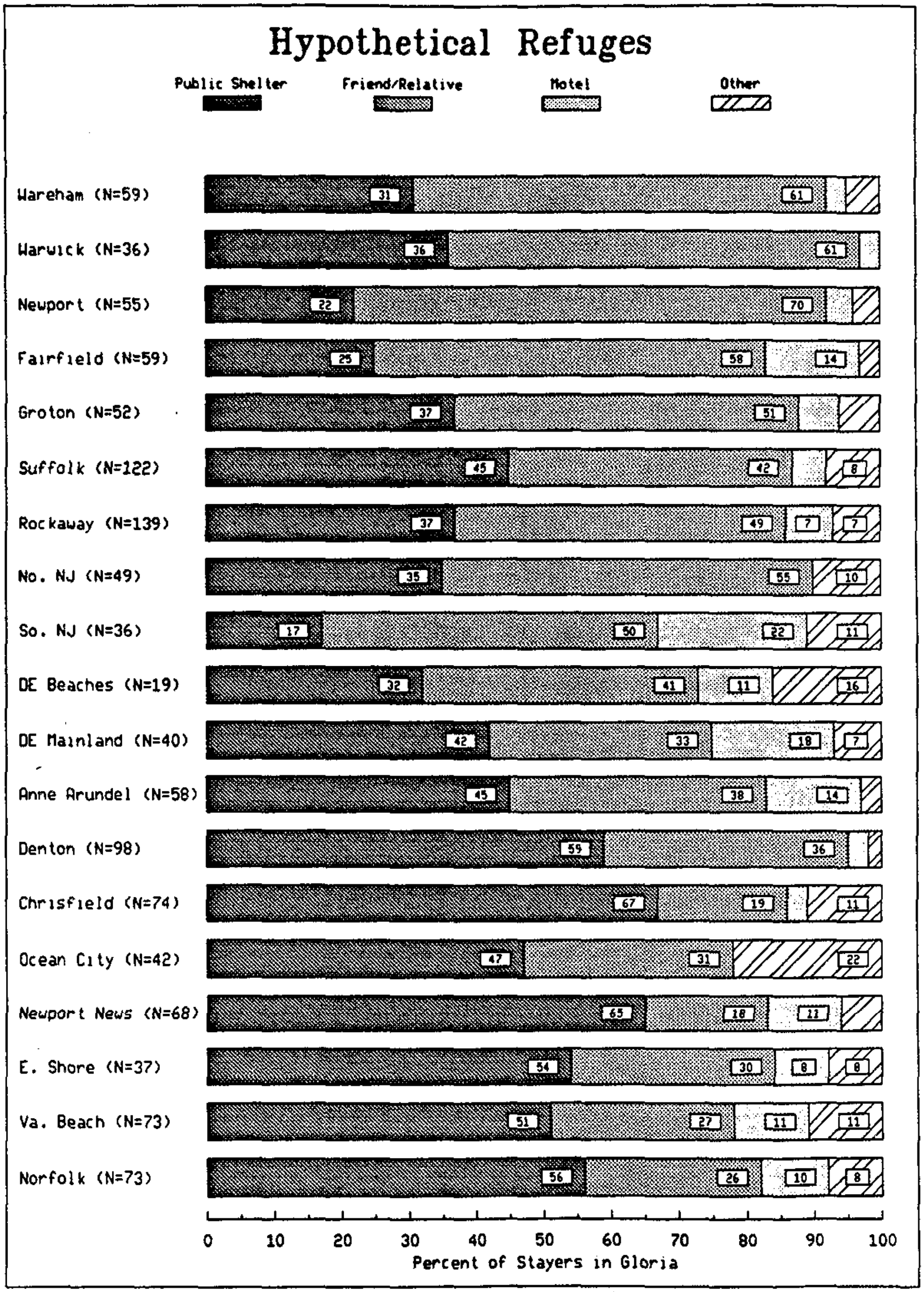
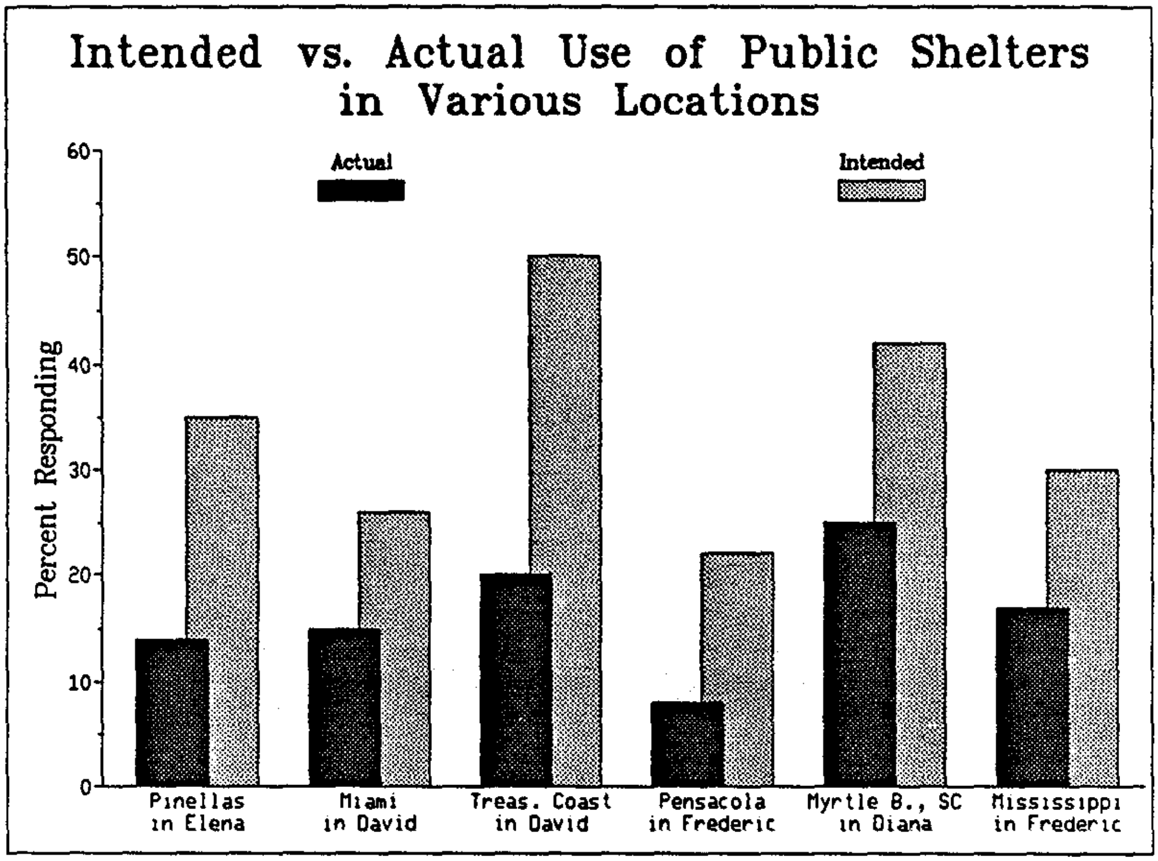

Hypothetical Refuges
Public Shelter
Friend/Relative
Motel
Other
Wareham (N=59)
31
61
Warwick (N=36)
36
61
Newport (N=55)
22
70
Fairfield (N=59)
25
58
14
Groton (N=52)
37
51
Suffolk (N=122)
45
42
8
Rockaway (N=139)
37
49
7
7
No. NJ (N=49)
35
55
10
So. NJ (N=36)
17
50
22
11
DE Beaches (N=19)
32
41
11
16
DE Mainland (N=40)
42
33
18
7
Anne Arundel (N=58)
45
38
14
Denton (N=98)
59
36
Chrisfield (N=74)
67
19
11
Ocean City (N=42)
47
31
22
Newport News (N=68)
65
18
11
E. Shore (N=37)
54
30
8
8
Va. Beach (N=73)
51
27
11
11
Norfolk (N=73)
56
26
10
8
0
10
20
30
40
50
60
70
80
90
100
Percent of Stayers in Gloria

FIG. 27



Intended vs. Actual Use of Public Shelters in Various Locations
Actual
Intended
Percent Responding
60
50
40
30
20
10
0
Pinellas in Elena
Miami in David
Treas. Coast in David
Pensacola in Frederic
Myrtle B., SC in Diana
Mississippi in Frederic

FIG. 28

hypothetical interview. It is also likely that as evacuation nears, people consider the pro's and con's of public shelters more carefully, with many deciding in retrospect that public shelter conditions are not so attractive after all.

Although hypothetical shelter use figures are not reliable in the absolute sense, they do have some validity in a relative sense. That is, if more people in one location say they would use public shelters than people in a second location, more of them probably will actually use public shelters in an evacuation, although the hypothetical numbers from both groups are inflated. More people in the southern area sample said they would use public shelters than in the northern sample, for example. This also appeared true, but less definitely, in the actual response data.

It's interesting that the income vs. shelter use relationship discussed earlier and not verified in Gloria is clearly present with hypothetical shelter use data (Figure 29). This gives a bit more reason for applying the generalization when deriving planning assumptions for the region.

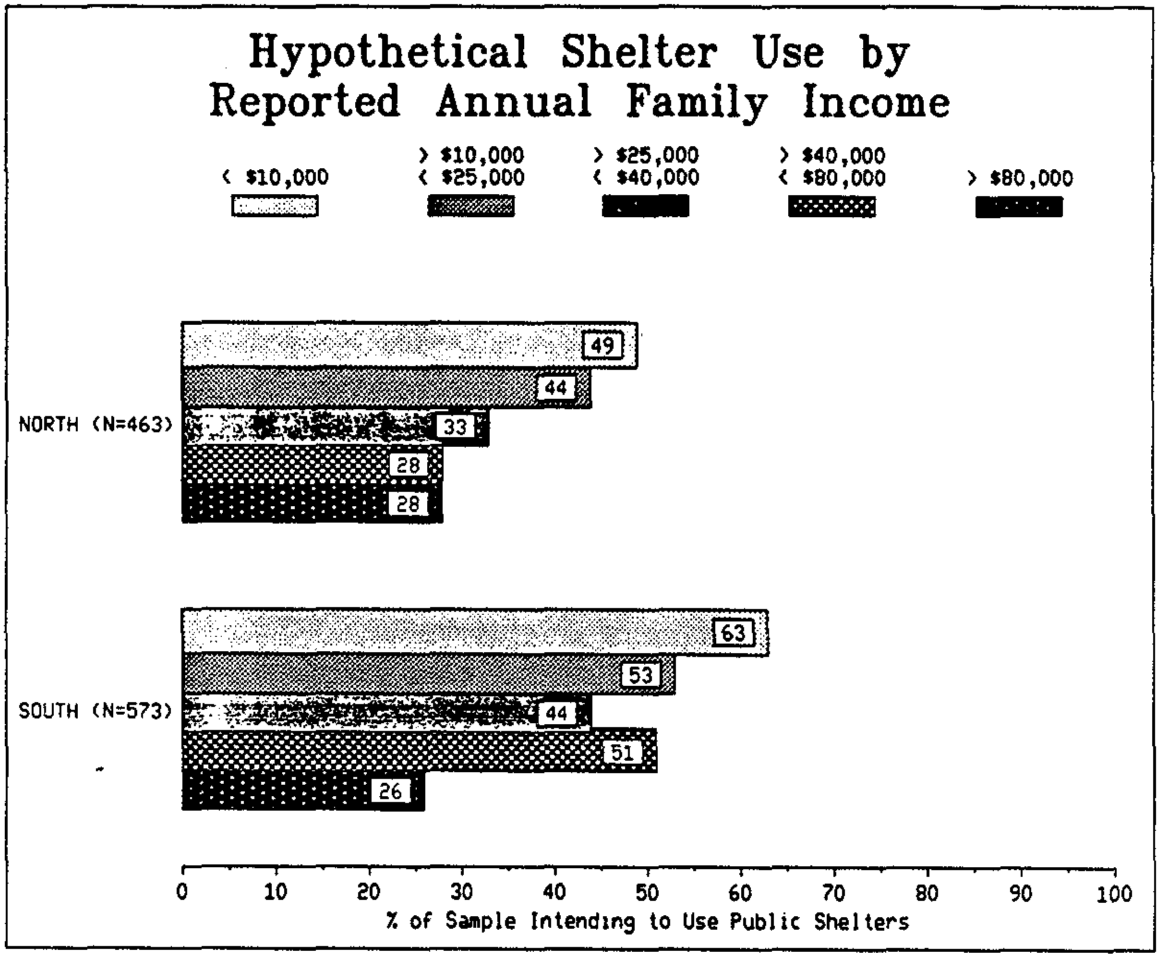

Hypothetical Shelter Use by
Reported Annual Family Income
< $10,000
> $10,000
< $25,000
> $25,000
< $40,000
> $40,000
< $80,000
> $80,000
NORTH (N=463)
49
44
33
28
28
SOUTH (N=573)
63
53
44
51
26
0
10
20
30
40
50
60
70
80
90
100
% of Sample Intending to Use Public Shelters

FIG. 29

Evacuation Destinations

Response in Gloria

There was much variation from site to site with respect to whether evacuees in Gloria left their local areas (usually meaning towns) or sought refuge nearby (Figure 30). Only 7% of the evacuees in Newport News left their local area, compared to 88% in the southern New Jersey area. In half the locations more than 50% of the evacuees went out-of-town.

Figure 31 suggests, though, that most evacuees didn't go very far, even if it was out-of-town. In 13 of 18 sites more than half the evacuees said they reached their destination in 30 minutes or less. In the New England states between 83% and 100% of the evacuees took less than 30 minutes.

It was noted previously that very few of the people going out of their local area went to public shelters, and that is common throughout the Gulf and Atlantic coasts. In most locations people in the highest risk locations (barrier islands primarily) are more likely to go out-of-town than evacuees from lower-risk areas. The proximity-to-water test tends to verify that generalization for Gloria in the southern area but not in the northern area (Fig. 32). Proximity to water, however, is not a good surrogate for hazardousness in all locations or when comparing one site to another. When simply looking at interview sites consisting primarily of beach areas (Delaware beaches, southern New Jersey, Ocean City, MD, etc.), it appears that those locations had substantially more evacuees leaving the local area and taking more than 30 minutes to reach their destinations than did most other sites.

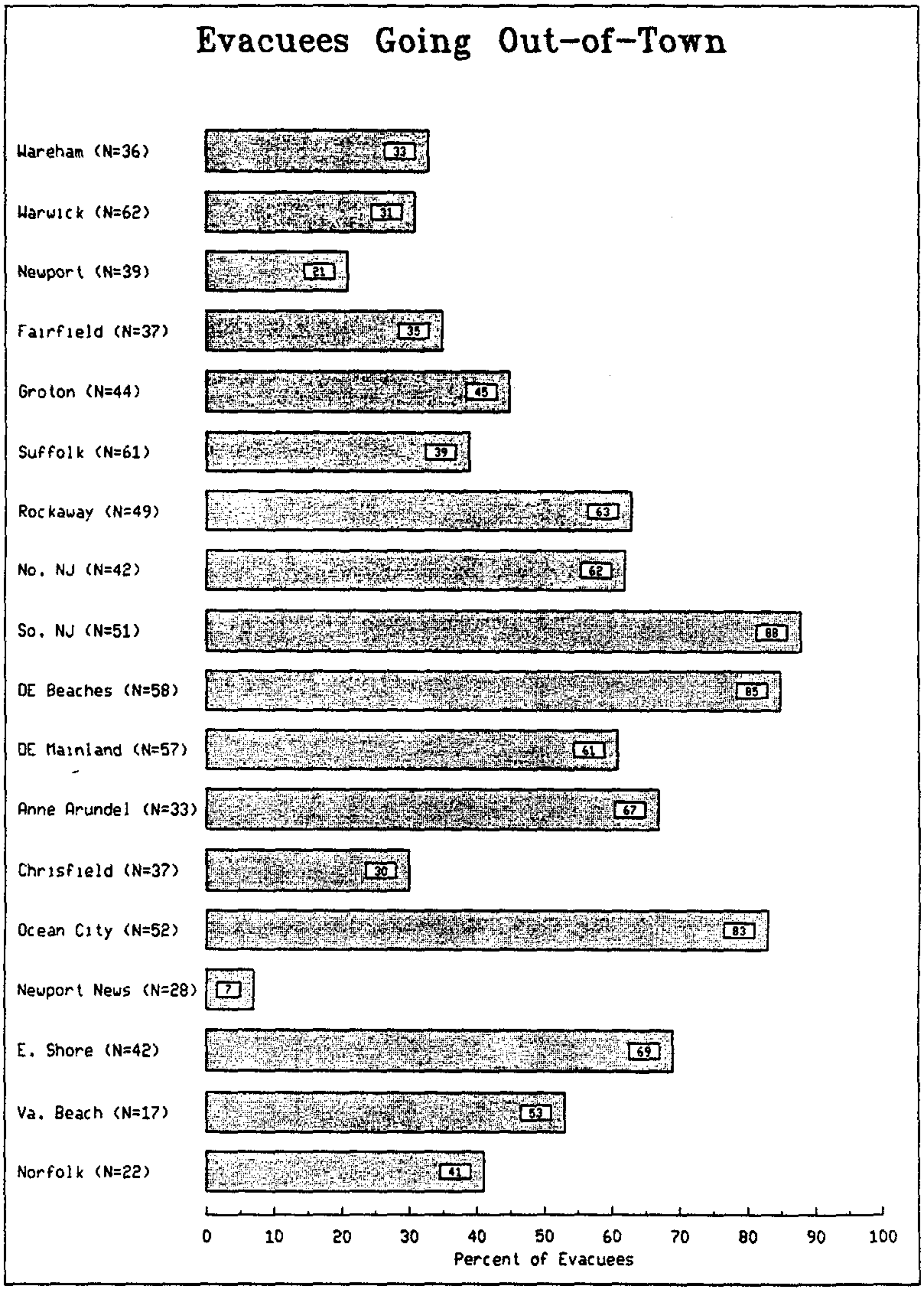
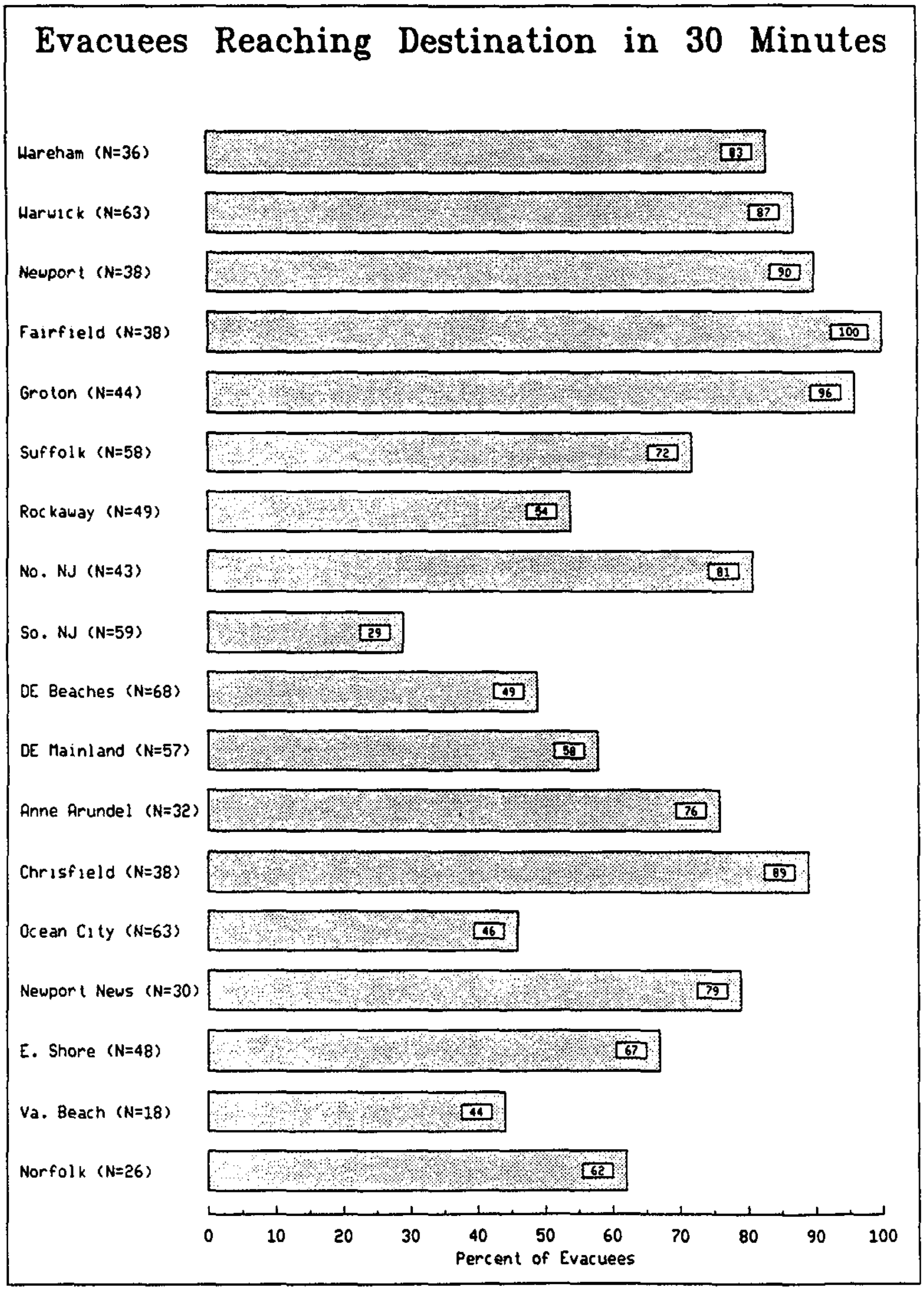

Evacuees Going Out-of-Town
Wareham (N=36)
33
Warwick (N=62)
31
Newport (N=39)
21
Fairfield (N=37)
35
Groton (N=44)
45
Suffolk (N=61)
39
Rockaway (N=49)
63
No. NJ (N=42)
62
So. NJ (N=51)
88
DE Beaches (N=58)
85
DE Mainland (N=57)
61
Anne Arundel (N=33)
67
Chrisfield (N=37)
30
Ocean City (N=52)
83
Newport News (N=28)
7
E. Shore (N=42)
69
Va. Beach (N=17)
53
Norfolk (N=22)
41
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuees

FIG. 30



Evacuees Reaching Destination in 30 Minutes
Wareham (N=36)
Warwick (N=63)
Newport (N=38)
Fairfield (N=38)
Groton (N=44)
Suffolk (N=58)
Rockaway (N=49)
No. NJ (N=43)
So. NJ (N=59)
DE Beaches (N=68)
DE Mainland (N=57)
Anne Arundel (N=32)
Chrisfield (N=38)
Ocean City (N=63)
Newport News (N=30)
E. Shore (N=48)
Va. Beach (N=18)
Norfolk (N=26)
83
87
90
100
96
72
54
81
29
49
58
76
89
46
79
67
44
62
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuees

FIG. 31

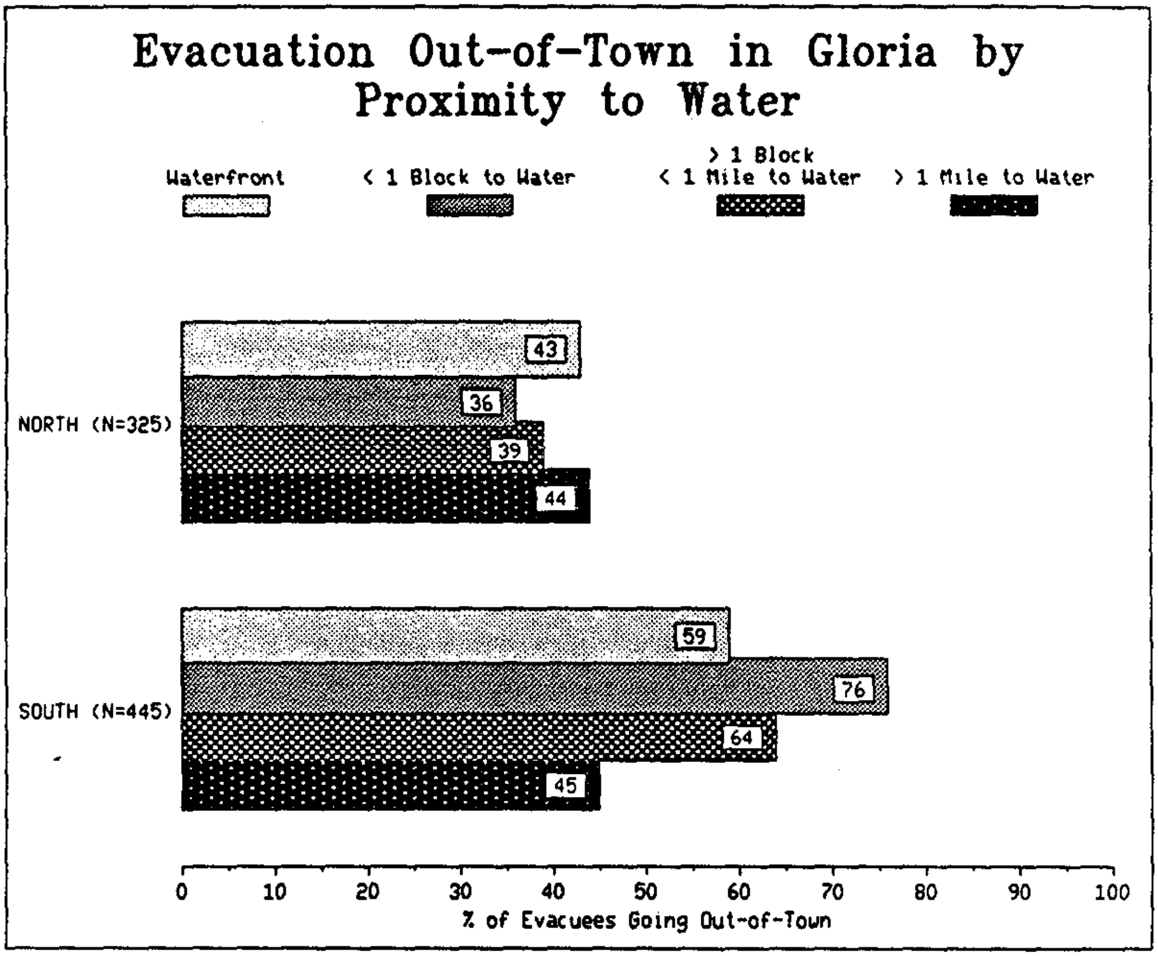
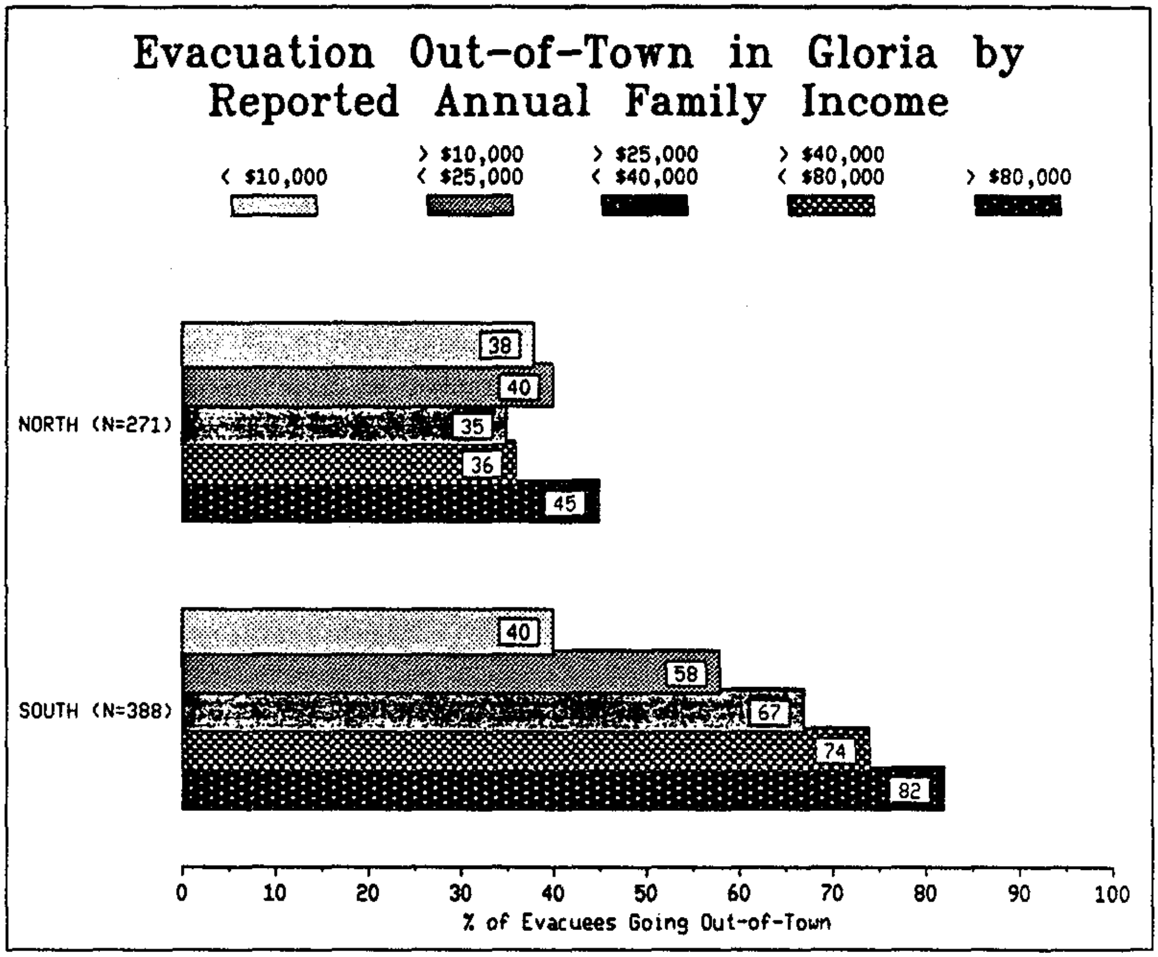

Evacuation Out-of-Town in Gloria by Proximity to Water
Waterfront
< 1 Block to Water
> 1 Block
< 1 Mile to Water
> 1 Mile to Water
NORTH (N=325)
43
36
39
44
SOUTH (N=445)
59
76
64
45
0
10
20
30
40
50
60
70
80
90
100
% of Evacuees Going Out-of-Town

FIG. 32

Income can also be a clue to whether evacuees will leave their local area. This probably results from the fact that people with higher incomes are more likely to live near the beach, they are less likely to use public shelters, and they can more easily afford motels. In the Gloria data there was no income vs. out-of-town evacuation relationship in the southern sample, but there was in the northern area (Fig. 33).

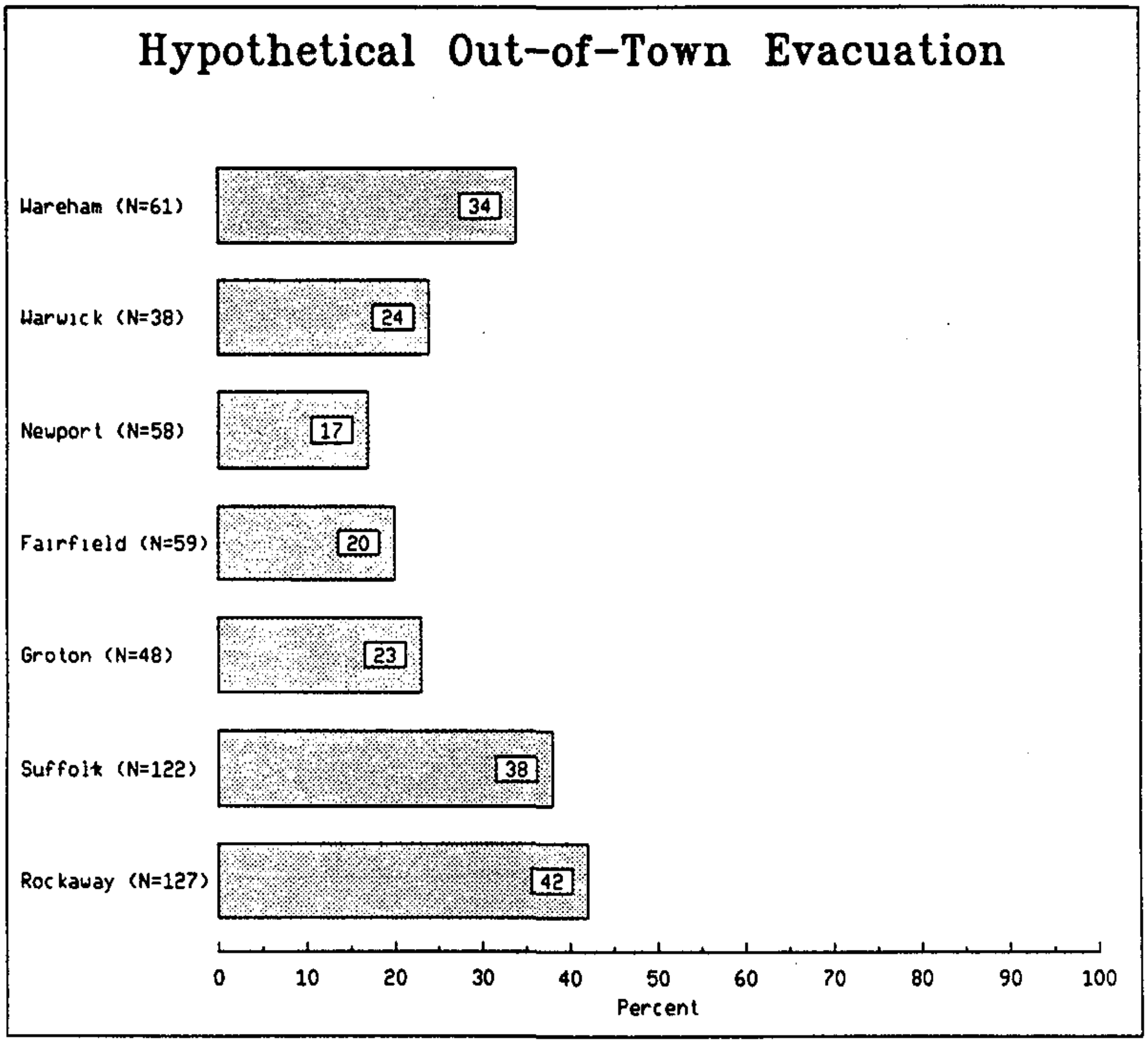
Hypothetical Responses

In the northern area people who didn't evacuate in Gloria were asked where they thought they would have gone if they had evacuated. The results were fairly consistent with actual response data for the sites (Fig. 34). Higher income respondents were somewhat more likely to say they would leave the local area (Fig. 35).



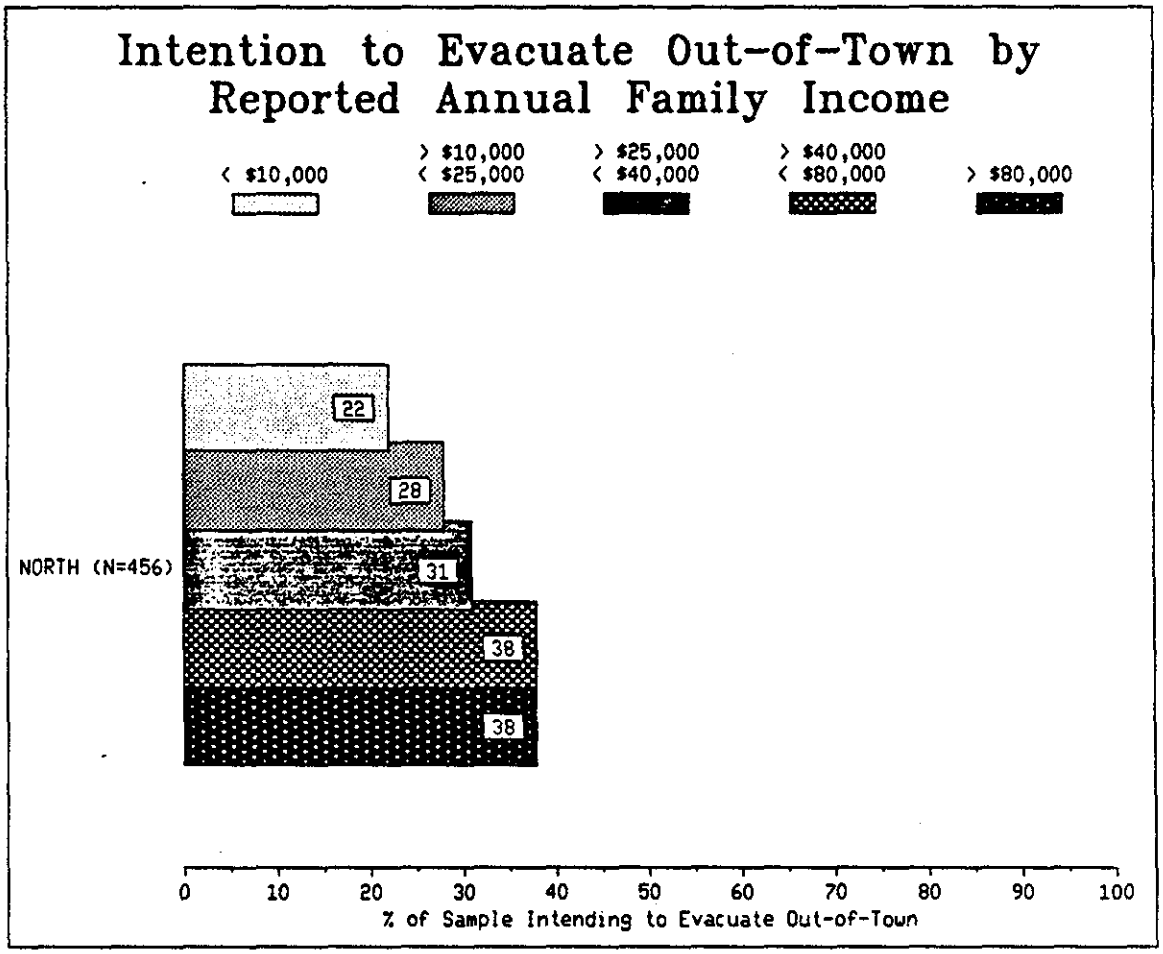
Evacuation Out-of-Town in Gloria by
Reported Annual Family Income
< $10,000
> $10,000
< $25,000
> $25,000
< $40,000
> $40,000
< $80,000
> $80,000
NORTH (N=271)
38
40
35
36
45
SOUTH (N=388)
40
58
67
74
82
0
10
20
30
40
50
60
70
80
90
100
% of Evacuees Going Out-of-Town

FIG. 33



Hypothetical Out-of-Town Evacuation
Wareham (N=61)
Warwick (N=38)
Newport (N=58)
Fairfield (N=59)
Groton (N=48)
Suffolk (N=122)
Rockaway (N=127)
34
24
17
20
23
38
42
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 34



Intention to Evacuate Out-of-Town by
Reported Annual Family Income
< $10,000
> $10,000
< $25,000
> $25,000
< $40,000
> $40,000
< $80,000
> $80,000
NORTH (N=456)
22
28
31
38
38
0
10
20
30
40
50
60
70
80
90
100
% of Sample Intending to Evacuate Out-of-Town

FIG. 35

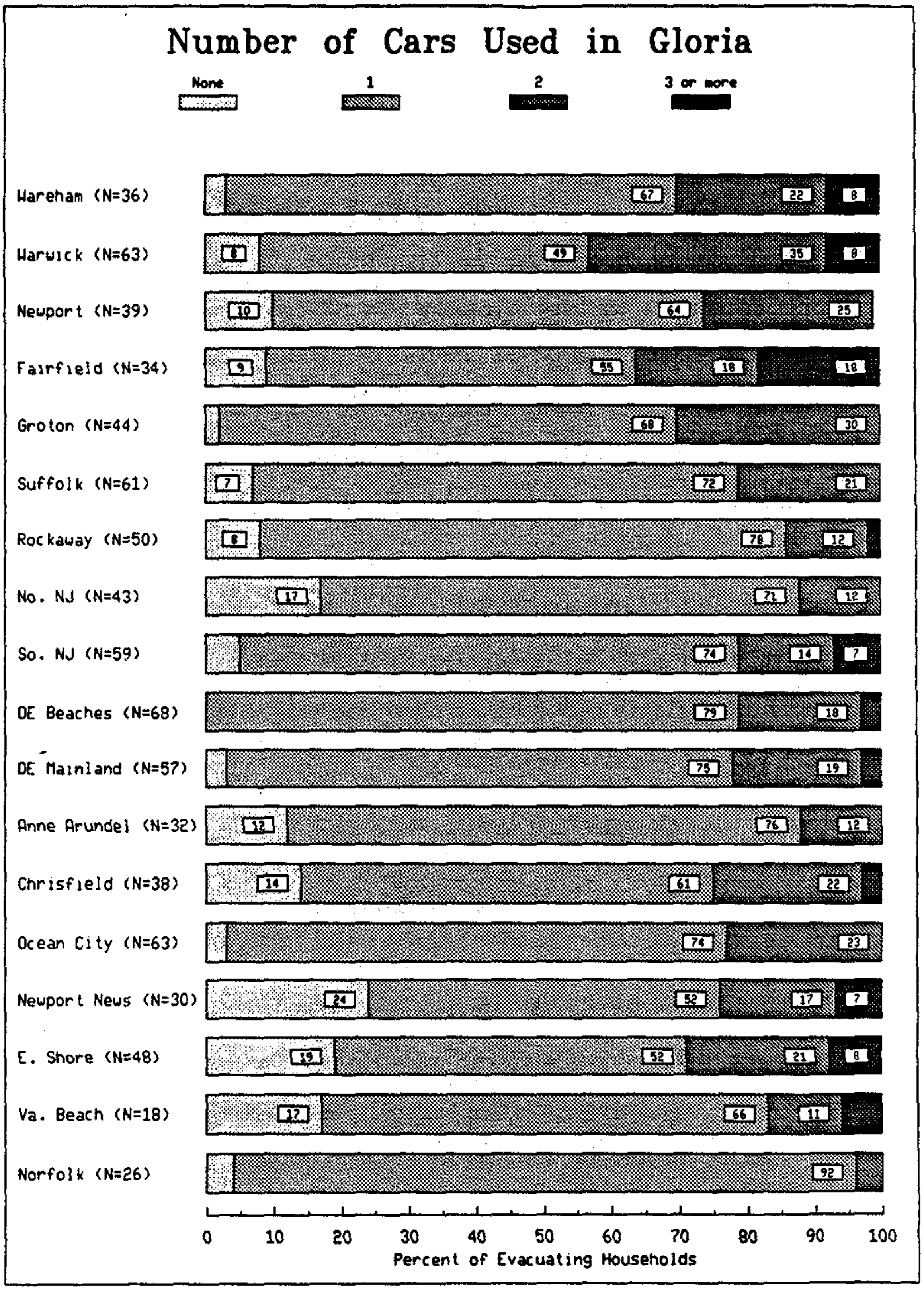
Vehicle Use

Household Transportation

The great majority of evacuees in Gloria used only one vehicle, although some used more (Figure 36). That is almost always the case in hurricane evacuations. Figure 37 shows two additional variables: the percentage of available vehicles actually used by evacuating households and the average number of vehicles used per evacuating household. The average ranged from 1.0 to 1.5. In most cases between 65% and 75% of the vehicles available to households are actually used in evacuating. Fourteen of eighteen Gloria sites were within one percentage point of that range. The Delaware beach sample was abnormally high, and Virginia Beach and Anne Arundel were unusually low. Not all vehicles are used in evacuations because families want to avoid separating any more than necessary.

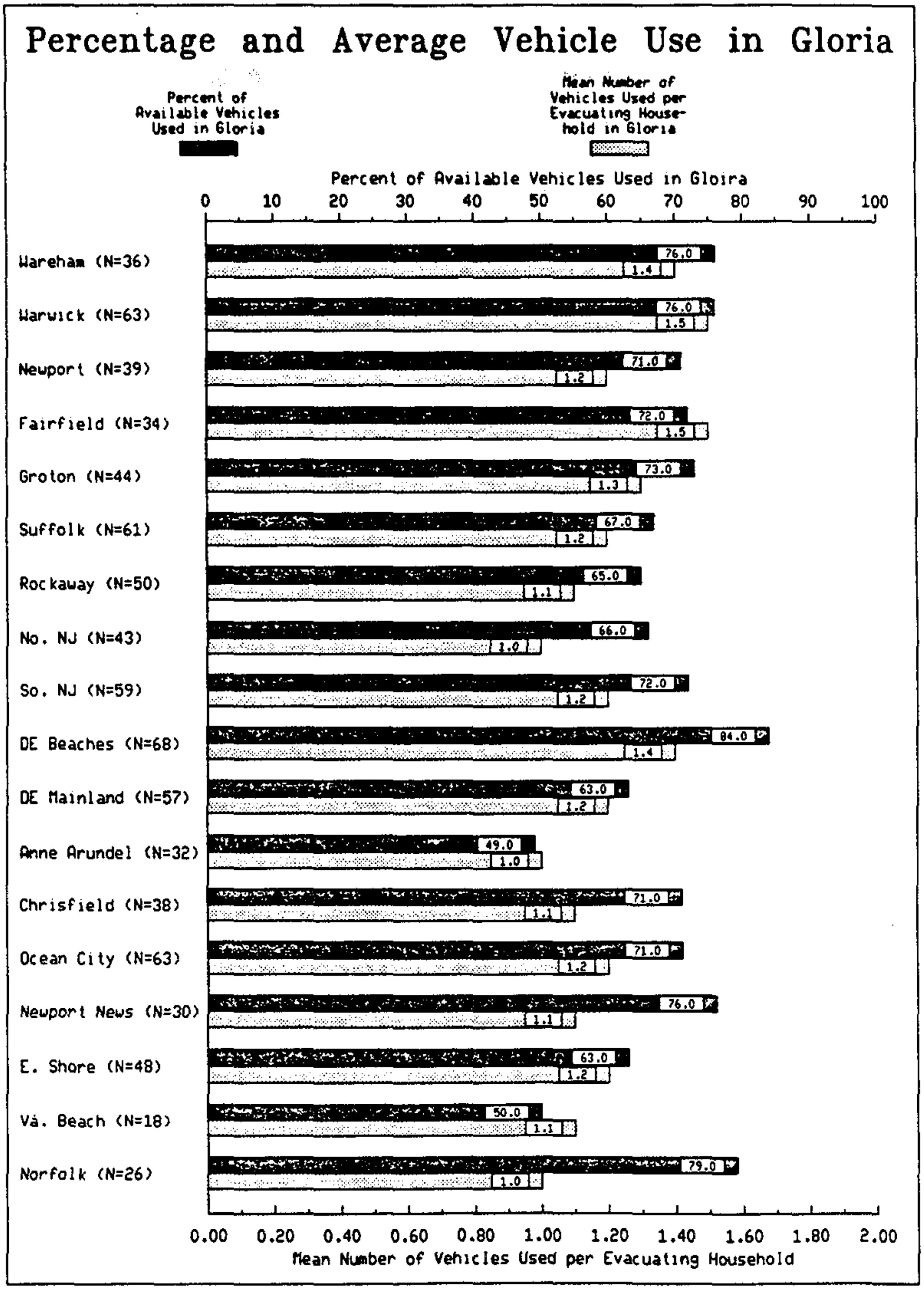
Public Transportation

In the northern area evacuees were asked what sort of transportation they used (Fig. 38). Almost everyone said they left in their own vehicle. Only in Rockaway did anyone mention using public transportation. Northern area respondents not leaving in Gloria were asked whether they had a car available in which to evacuate if they had chosen to (Fig. 39). Only in Rockaway, and to a much lesser degree Newport, did people say no. Recall also that people in only three sites said they didn't leave because of a lack of transportation (Ocean City,



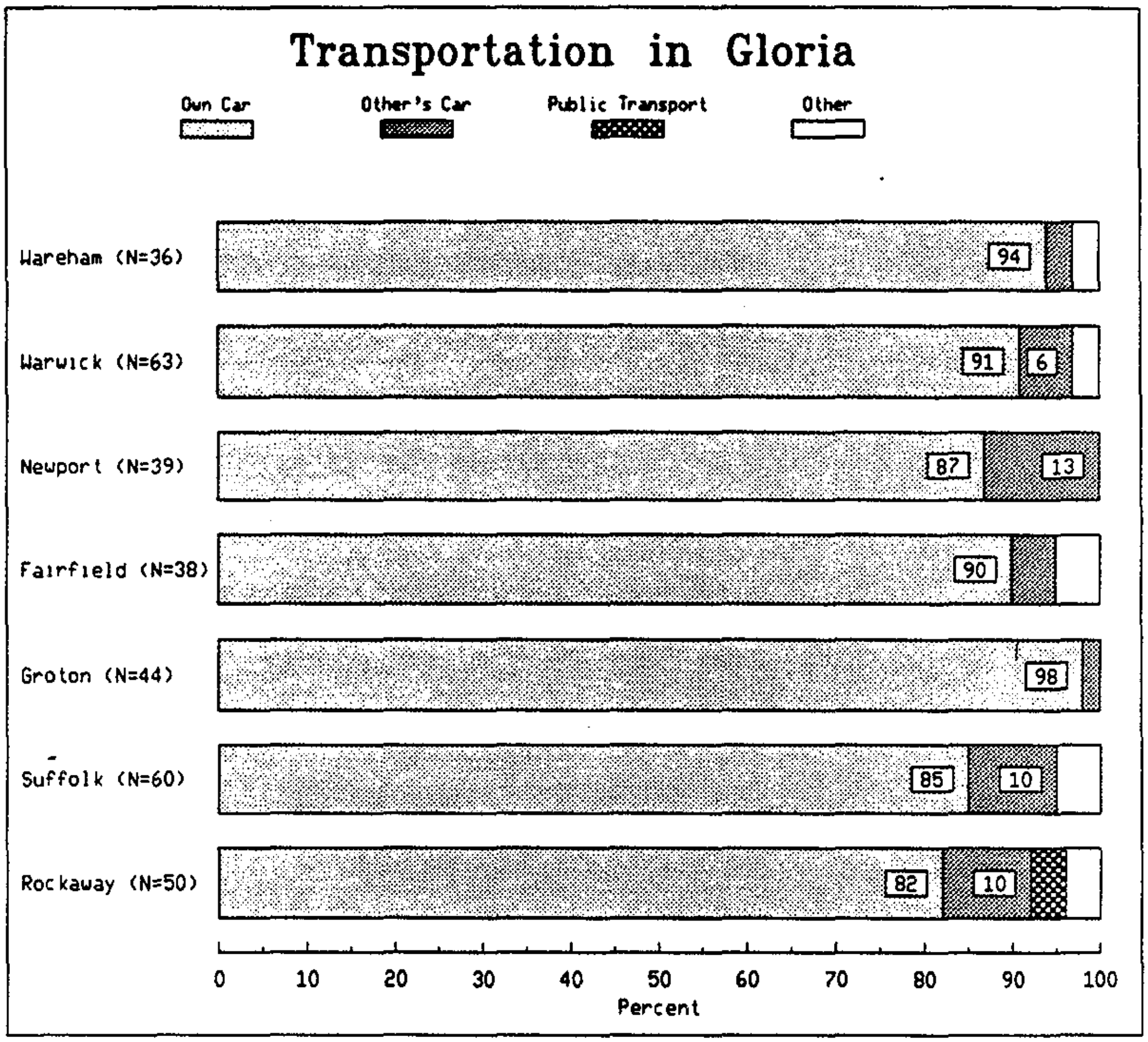
Number of Cars Used in Gloria
None
1
2
3 or more
Wareham (N=36)
Warwick (N=63)
Newport (N=39)
Fairfield (N=34)
Groton (N=44)
Suffolk (N=61)
Rockaway (N=50)
No. NJ (N=43)
So. NJ (N=59)
DE Beaches (N=68)
DE Mainland (N=57)
Anne Arundel (N=32)
Chrisfield (N=38)
Ocean City (N=63)
Newport News (N=30)
E. Shore (N=48)
Va. Beach (N=18)
Norfolk (N=26)
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuating Households

FIG. 36



Percentage and Average Vehicle Use in Gloria
Percent of Available Vehicles Used in Gloria
Mean Number of Vehicles Used per Evacuating Household in Gloria
Percent of Available Vehicles Used in Gloira
0 10 20 30 40 50 60 70 80 90 100
Wareham (N=36) 76.0 1.4
Warwick (N=63) 76.0 1.5
Newport (N=39) 71.0 1.2
Fairfield (N=34) 72.0 1.5
Groton (N=44) 73.0 1.3
Suffolk (N=61) 67.0 1.2
Rockaway (N=50) 65.0 1.1
No. NJ (N=43) 66.0 1.0
So. NJ (N=59) 72.0 1.2
DE Beaches (N=68) 84.0 1.4
DE Mainland (N=57) 63.0 1.2
Anne Arundel (N=32) 49.0 1.0
Chrisfield (N=38) 71.0 1.1
Ocean City (N=63) 71.0 1.2
Newport News (N=30) 76.0 1.1
E. Shore (N=48) 63.0 1.2
Va. Beach (N=18) 50.0 1.1
Norfolk (N=26) 79.0 1.0
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
Mean Number of Vehicles Used per Evacuating Household

FIG. 37



Transportation in Gloria
Own Car
Other's Car
Public Transport
Other
Wareham (N=36)
Warwick (N=63)
Newport (N=39)
Fairfield (N=38)
Groton (N=44)
Suffolk (N=60)
Rockaway (N=50)
94
91
6
87
13
90
98
85
10
82
10
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 38

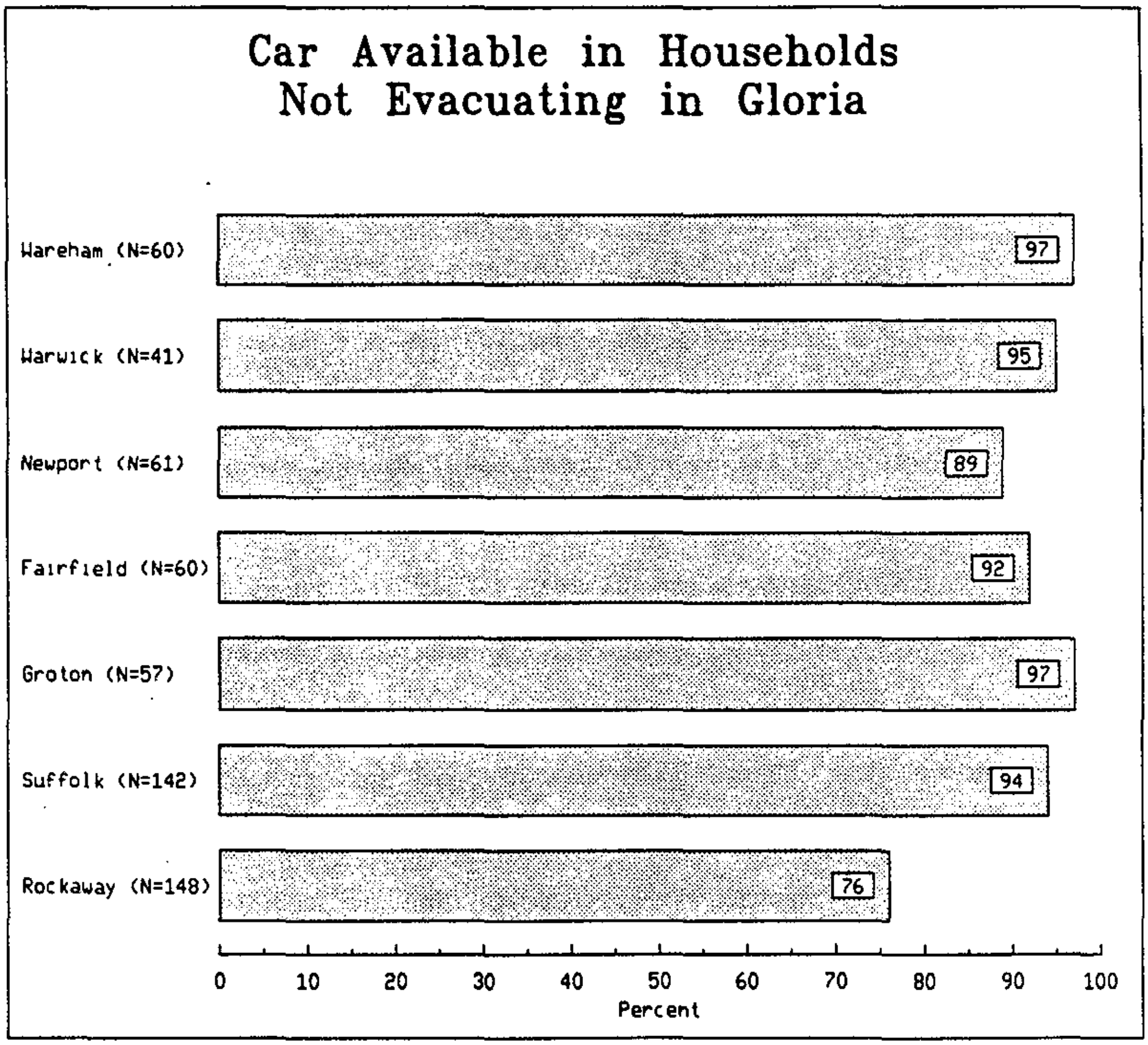

Car Available in Households
Not Evacuating in Gloria
Wareham (N=60)
97
Warwick (N=41)
95
Newport (N=61)
89
Fairfield (N=60)
92
Groton (N=57)
97
Suffolk (N=142)
94
Rockaway (N=148)
76
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 39

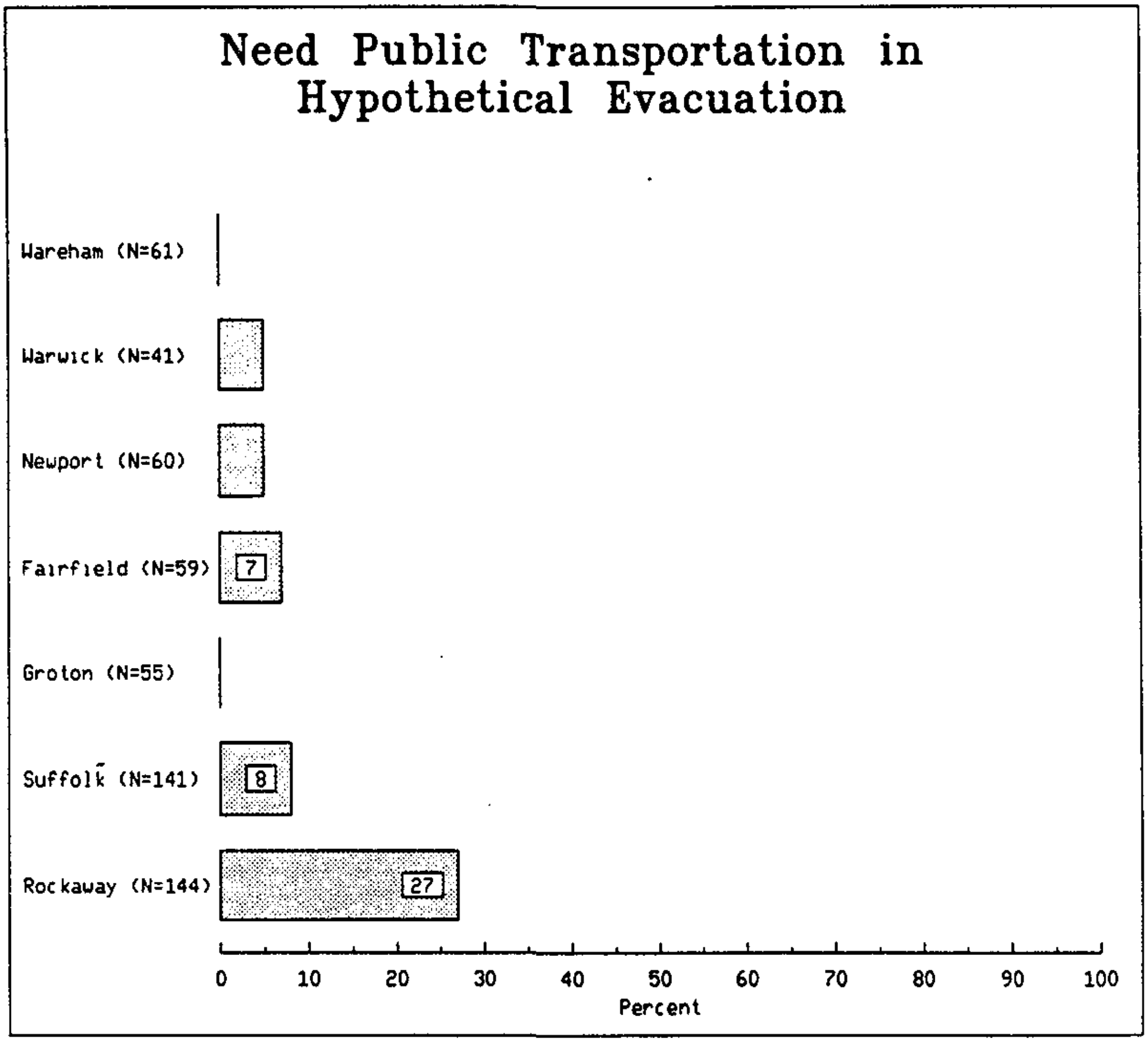
MD, Denton, and Rockaway) and in those cases it was 5% or fewer (of the nonevacuees). Rockaway (the question being asked only in the northern area) also had the greatest incidence of people saying they would need to use public transportation if they evacuated (Fig. 40).

Evacuation Assistance

Evacuees in all sites were asked whether they required outside assistance in evacuating in Gloria (Fig. 41). Very few said they did. In most locations no one said they needed help from an agency to evacuate, and of those who did, the figure was 5% or less every place except Chrisfield where it was 11% (+ or - 10% points).

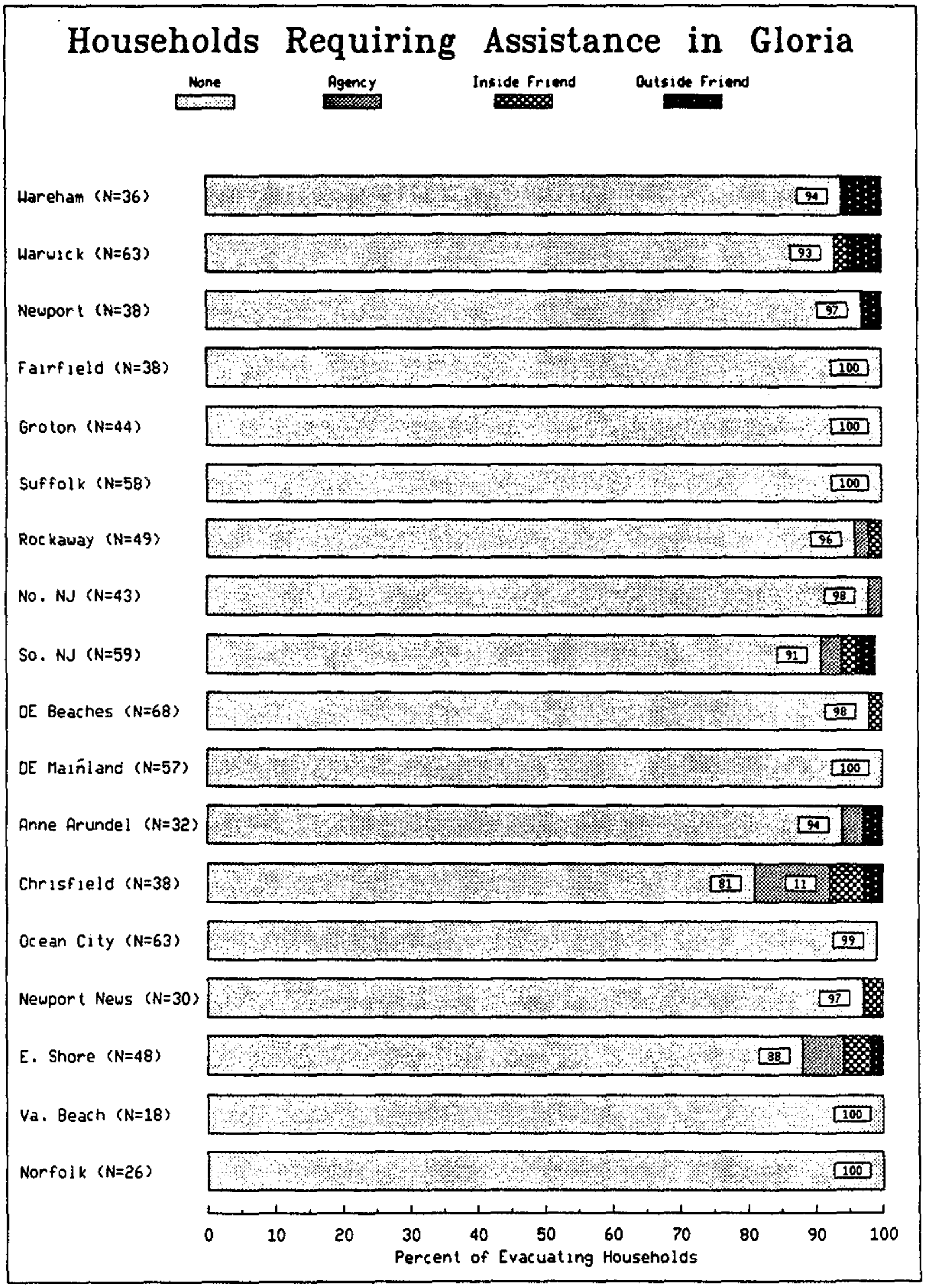
Respondents not evacuating in Gloria were asked whether they would need help if they evacuated (Fig. 42). The question was asked the same way in the northern and southern areas, but responses were coded in more detail in the northern area. Thus, in the southern area there is the "yes, general" category, whereas in the northern area it is broken down into "yes, agency" and "yes, other." Variation in response was substantial from site to site. Where they could be specific, few said they would need agency assistance. In the southern area it's probably reasonable to assume that agency dependence would be comparable to that mentioned in the northern area. Newport News had the highest overall percentage saying help would be needed from someone outside the home.

These figures are not unusual. Most help from outside the household usually comes from friends and relatives. Even when residents believe they would require agency assistance, friends or relatives usually fill the need instead.



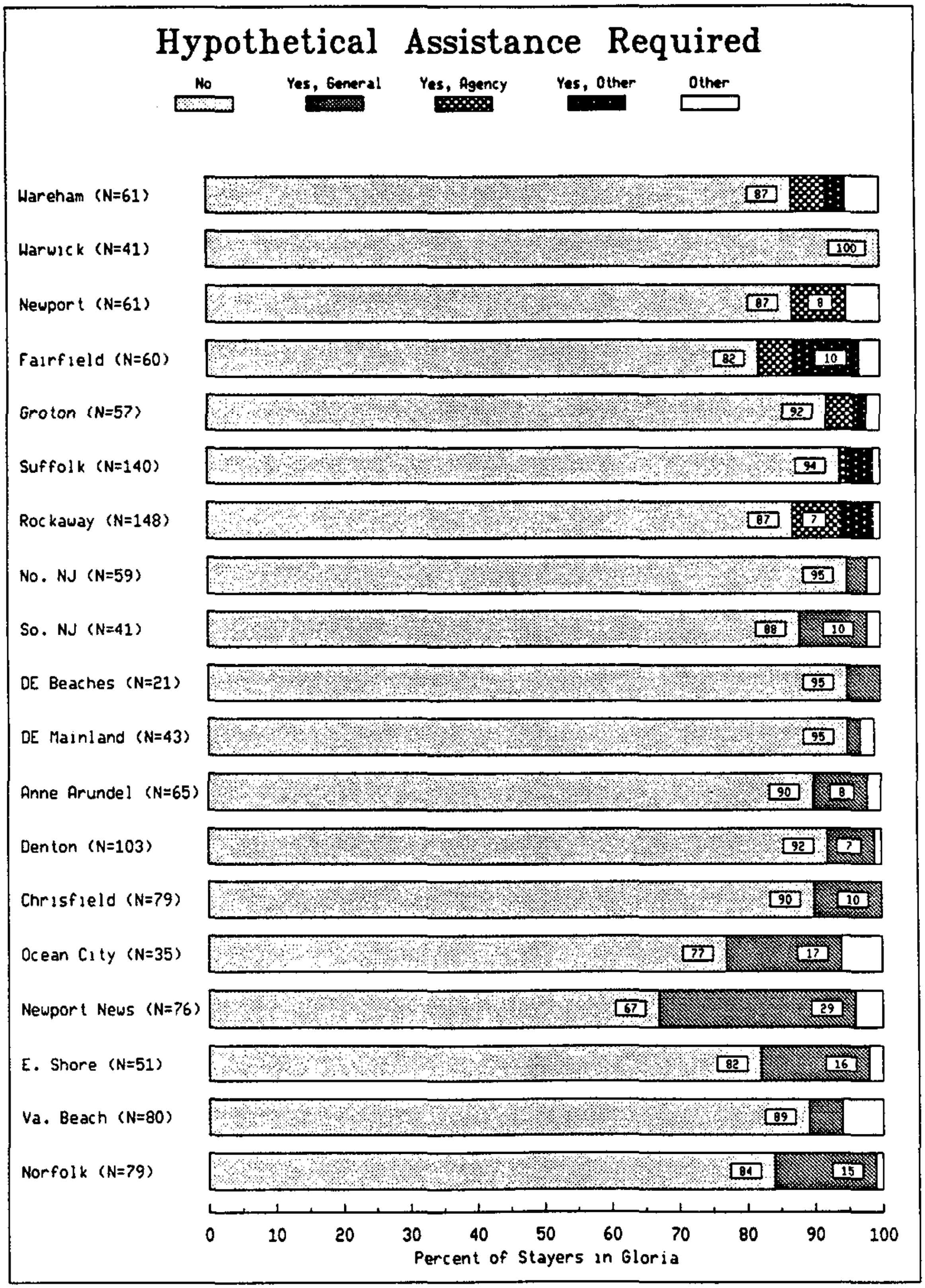
Need Public Transportation in Hypothetical Evacuation
Wareham (N=61)
Warwick (N=41)
Newport (N=60)
Fairfield (N=59)
7
Groton (N=55)
Suffolk (N=141)
8
Rockaway (N=144)
27
0
10
20
30
40
50
60
70
80
90
100
Percent

FIG. 40



Households Requiring Assistance in Gloria
None
Agency
Inside Friend
Outside Friend
Wareham (N=36)
94
Warwick (N=63)
93
Newport (N=38)
97
Fairfield (N=38)
100
Groton (N=44)
100
Suffolk (N=58)
100
Rockaway (N=49)
96
No. NJ (N=43)
98
So. NJ (N=59)
91
DE Beaches (N=68)
98
DE Mainland (N=57)
100
Anne Arundel (N=32)
94
Chrisfield (N=38)
81
11
Ocean City (N=63)
99
Newport News (N=30)
97
E. Shore (N=48)
88
Va. Beach (N=18)
100
Norfolk (N=26)
100
0
10
20
30
40
50
60
70
80
90
100
Percent of Evacuating Households

FIG. 41



Hypothetical Assistance Required
No
Yes, General
Yes, Agency
Yes, Other
Other
Wareham (N=61)
Warwick (N=41)
Newport (N=61)
Fairfield (N=60)
Groton (N=57)
Suffolk (N=140)
Rockaway (N=148)
No. NJ (N=59)
So. NJ (N=41)
DE Beaches (N=21)
DE Mainland (N=43)
Anne Arundel (N=65)
Denton (N=103)
Chrisfield (N=79)
Ocean City (N=35)
Newport News (N=76)
E. Shore (N=51)
Va. Beach (N=80)
Norfolk (N=79)
87
100
87
8
82
10
92
94
87
7
95
88
10
95
95
90
8
92
7
90
10
77
17
67
29
82
16
89
84
15
0 10 20 30 40 50 60 70 80 90 100
Percent of Stayers in Gloria

FIG. 42

Appendix I

Questionnaire Used in Survey

HURRICANE GLORIA/MID-ATLANTIC/NORTHEAST SURVEY
PHASE II
NOVEMBER, 1987

1. Did you leave your home to go someplace safer in response to the hurricane threat?

   1 Yes (GO TO Q.2)
   5 No (SKIP TO Q.11)
   7 Other (GO TO Q.2, IF APPLICABLE)

2. Did you go to a:

   1 Public Shelter
   3 Friend or Relative's Home
   5 Hotel/Motel
   7 Other (______)

3. Where was that located?

   1 Locally (in same town as residence)
   5 Out-of-town (______________________)
   (Specify name of town)

4. What convinced you to go someplace safer? (CODE UP TO 3 RESPONSES)

   22 Advice or order by elected officials
   33 Advice from Weather Service
   44 Advice/order from police or fireman
   55 Advice from media
   66 Advice from friend/relative
   77 Concern about severity of storm
   88 Concern that storm <u>might</u> hit
   91 Heard probability (odds) of hit
   95 Other: (______________________)
   (Specify)

5. When did you leave your home to go someplace safer?

   TIME: ☐☐ : ☐☐ AM ☐

   PM ☐

   DATE:

M	T	W	R	F	SA	SU
23	24	25	26	27	28	29

6. How long did it take you to get to where you were going?

   __ __.__ Hrs (to nearest 1/2 hr)

   (Never reached original destination=99.9)

7. When did you first return home from the place to which you evacuated?

T	W	R	F	SA	SU	M	T
24	25	26	27	28	29	30	31

8. Did you or anyone in your household require special assistance in evacuating?

   1 No
   3 Yes, by agency
   5 Yes, by friend or relative within household
   7 Yes, by friend or relative outside household
   9 Don't Know/Not Sure

8a. Did your household use your own vehicle(s) in evacuating, leave with someone else in theirs, or did you use public transportation?

   1 Own
   3 Other's
   5 Public Transportation
   7 Other ____________________

9. How many vehicles did your household take in evacuating?

   ____

10. How many vehicles were available to take in evacuating?

   ____ (GO TO Q.12)

NON-EVACUEES ONLY

11. What made you decide not to go anyplace else? (CODE UP TO 3 RESPONSES)

   05 Storm not severe/house adequate
   20 Officials said evacuation unnecessary
   30 Media said evacuation unnecessary
   35 Friend/relative said evacuation unnecessary
   45 Probabilities indicated low chance of hit
   55 Information indicated storm wouldn't hit
   60 No Officials said to evacuate
   65 Had no transportation
   70 Had no place to go
   75 Wanted to protect against looters
   80 Wanted to protect against storm
   85 Left unnecessarily in past
   90 Job required staying
   95 Other:____________________

FOR EVERYONE:

12. *Did you hear from anyone in an official position -- civil defense, the mayor's office, the governor, police -- that you should evacuate to a safer place?*

1 Yes
-------- 5 No (GO TO Q.14)
-------- 9 Don't Know (GO TO Q.14)

13. Did they say that you should evacuate or that you must evacuate?

1 Should
5 Must
9 Don't Know

-->14. How well do you think the warning and evacuation process was handled in the Gloria threat?

11 Good/OK
22 Traffic a problem
33 Not enough information
55 Shouldn't have been told to evacuate
66 Shelters bad, crowded, etc.
77 Other: ____________________

14a. Do you think your home would be safe to stay in if a major hurricane were to strike this area directly?

1 No
3 Yes
5 Don't Know

15. Would you do anything differently if you were in the same situation again? (CODE UP TO 3 RESPONSES)

11 Would evacuate
22 Wouldn't evacuate
33 Would leave earlier
44 Would wait later to leave
55 Would go further away
66 Wouldn't go as far
77 Would go to public shelter
88 Wouldn't go to public shelter
90 No
95 Other ____________________

EVACUEES, SKIP TO Q.18

NON-EVACUEES ONLY

16. If you evacuate in a future hurricane, would you go to:

1 A Friend/Relative's Home
3 A Hotel/Motel
5 A Public Shelter
7 Other
9 Don't Know/Not Sure

16a. Where specifically would you go if you evacuated, someplace local or someplace out-of-town?

1 Local (same town/borough as residence)
5 Out-of-town (borough) (________)
9 Don't Know

17. Would you or anyone in your household need special assistance from anyone outside the household in evacuating?

1 Yes, from government agency
3 Yes, from other
5 No
7 Other ____________

17a. Do you have a car or other vehicle to use in evacuating?

1 Yes
3 No
5 Other

17b. If you evacuated, would you need to use public transportation?

1 Yes
3 No
5 Other
7 Don't Know

ASK OF ALL RESPONDENTS

The following questions are for statistical purposes only.

18. Which of the following structures do you live in?

1 High-rise (6 or more stories) Condo or Apartment
3 Detached Single Family Building
5 Mobile Home
7 Other
9 Don't Know/Refused

19. How far is your home from the water?

1 Waterfront on beach
3 Waterfront on Sound
5 Other Waterfront
2 Less than 1 block from beach
4 Less than 1 block from bay
6 Less than 1 block from water
7 More than 1 block, less than 1 mile from water
8 More than 1 mile from water
9 Don't Know/Refused

20. Which of the following ranges describes your household income for a year?

1 Less than $10,000
3 $10,000 to $24,999
5 $25,000 to $39,999
7 $40,000 to $79,999
8 over $80,000
9 Don't Know/Refused

21. How old were you on your last birthday?

1 Under 25
3 25 to 39
5 40 to 65
7 Over 65
9 Refused

Thank you, that completes our survey. Good Bye!

Hurricane Evacuation Behavioral Assumptions for Rhode Island

Appendix to
Hurricane Evacuation Behavior in the Middle Atlantic and Northeast States

Prepared by

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For

U.S. Army Corps of Engineers

October, 1988

Preface

This document is accompanied by a lengthier report titled *Hurricane Evacuation Behavior in the Middle Atlantic and Northeast States*, referred to hereafter as the "Main Report". That volume provides background information relevant to understanding the following discussion. In particular the Main Report describes methodology and data which form the basis for many of the recommendations included in this volume. On occasion this report will make reference to "MR-Fig. *x*", meaning a particular figure in the Main Report.

Sample survey results for two Rhode Island locations are reported in this document, but the reader should be aware that they are included as "tests" of the general response model's applicability to Rhode Island rather than to provide actual figures for evacuation planning. Even for the two sites themselves response in future hurricanes could be considerably different than that observed in Gloria.

Evacuation Rates Among Residents

The percentage of respondents in our sample who evacuated in Gloria varied considerably between interview sites. Sixty-one percent left from Warwick and 37% from Newport (MR-Fig. 8). This does not necessarily mean, however, that more should have left. Substantially more of the Warwick sample lived near water bodies (MR-Fig. 7).

More Warwick area respondents (51%) than Newport (39%) said they were told to evacuate (MR-Fig. 10). In both locations people hearing that they should leave were more than twice as likely to do so (84% vs. 38% in Warwick and 65% vs. 21% in Newport) (MR-Fig. 11). Respondents in Newport were more likely to interpret the evacuation notice as advisory than mandatory, but people in Warwick were about evenly divided (MR-Fig. 12). Overall all in the northern sampling region, people believing the notice to be mandatory were more likely to evacuate (MR-Fig. 13).

In Warwick 62% and in Newport 46% of those who *didn't* leave said they felt safe staying where they were (MR-Fig. 18). About half of all respondents in both locations perceived their houses to be safe in hurricanes (MR-Fig. 15).

Response in Gloria in both interview locations conforms to patterns predicted by the general response model. Table 1 summarizes the general guidelines for use in assigning evacuation rates to specific locations elsewhere in Rhode Island. The table varies response on the basis of four variables.

	Severe Storm Evacuation Ordered in High/Mod. Risk Areas, and Mobile Homes			Weak Storm Evacuation Ordered in High Risk Areas Only, and Mobile Homes	
Risk Area					
High	*Mod*	*Low*	*High*	*Mod*	*Low*
Housing Other Than Mobile Homes					
90%	80%	30%	80%	40%	20%
Mobile Homes					
90%	85%	60%	90%	75%	55%

Note:

Figures will be lower if officials are not successful in communicating orders.

Table 1. Evacuation rates to be used for planning in Rhode Island.

Storm Severity

The table addresses two storm scenarios. The first is a strong storm, a category 3 or worse. The second storm is weaker. The difference obviously is that more people are at risk in the more severe storm, and evacuation will be greater from moderate-risk and low-risk locations.

Action by Officials

It is assumed that officials will tell people to leave from high-risk and moderate-risk locations and tell all mobile home dwellers in coastal counties to evacuate in the severe storm. In the weaker storm only mobile home residents and people who live in high-risk locations are told to leave.

It is also assumed that officials are successful at communicating the evacuation notices to residents. The Gloria data attests to the greater likelihood of people leaving if they believe officials have told them to. The only way to ensure that everyone will hear the notice is to have it disseminated door-to-door. If that is not possible, vehicles with loudspeakers are the second best method. If officials cannot disseminate the evacuation notices in either of those manners, evacuation rates will be 25% lower in high-risk areas and 50% lower in moderate-risk and low-risk areas.

Risk Area

High-risk areas refer primarily to barrier islands and other land areas exposed to the open ocean where wave battering and scour are major hazards in addition to flooding. Moderate-risk areas are subject to flooding in moderate to strong storms but do not experience significant battering and scour. Low-risk areas are subject only to wind and are adjacent to moderate-risk locations. Most of the sample households in the two areas are located in high-risk to moderate-risk locations. More of the Warwick sample is probably high risk.

Housing

Table 1 distinguishes between mobile homes and other housing. Neither of the survey locations contained a large percentage of mobile homes, but they should be considered separately for planning. Evacuation will be greater from mobile homes than from other housing, all other factors being the same.

Evacuation Timing
By Residents

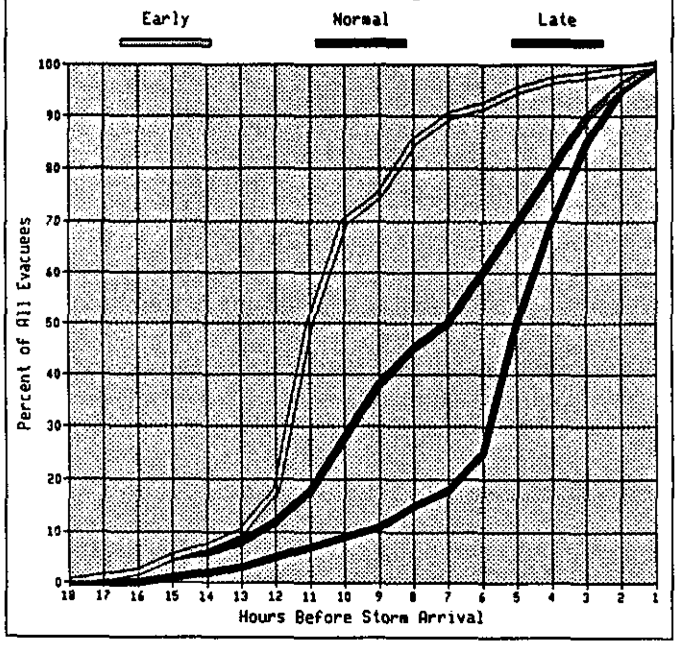
With so few evacuees in the two samples, it's difficult to make very confident statements about the exact time evacuees left. The matter is further complicated by the fact that interviewees were being asked to recall fairly precise information from something that occurred two years previously.

Evacuation timing, however, will vary greatly from storm to storm, and little can be generalized from Gloria. For planning purposes three different sets of assumptions depicted in Figure 1 should be analyzed. The three curves in Figure 1 reflect three different rates at which evacuees leave, reflecting in turn three different levels of urgency.

The left-most curve represents response when forecasts are early and residents are told to evacuate with plenty of warning. That scenario should probably be called optimistic. The middle curve is probably more typical. Warning is not quite so early in relation to landfall. Finally, the right-hand curve will pertain when a storm accelerates, intensifies, or changes course unexpectedly. People will leave very promptly if it is made clear to them that they must. All three curves should be used for planning because all three will occur eventually.

Fewer than 20% of eventual evacuees will leave before being told to leave. When told, however, people will leave as promptly as they believe they must. Given the luxury of time, most people will not evacuate late at night and will wait until morning if they haven't left by 11 pm or midnight. People <u>will</u> leave in the middle of the night if officials make it clear that circumstances make it imperative that they do so. People from high-risk locations (barrier islands) tend to leave earlier than other evacuees.

Fig. 1. Cumulative Response Curves for Planning



Demand for Public Shelters by Residents

Very few evacuees in either survey area used public shelters: 8% of the Warwick evacuees said they went to public shelters compared to 3% of the Newport evacuees (MR-Fig. 25). Due to the sample sizes, however, both figures are subject to enough uncertainty to prevent the conclusion that there were overall differences in shelter use among all evacuees from the two areas. Such figures are normal for high-risk locations. Residents of beach communities and waterfront locations usually have higher incomes and choose not to stay at public shelters and can afford motels if arrangements can't be made with friends and relatives. They also tend to leave earlier and go farther.

Late night evacuation tends to maximize shelter use, primarily because it is occurring with a sense of urgency, leaving no time to make alternative arrangements with friends, relatives, and motels or leaving too little time to travel the distance necessary to go out-of-town, particularly at night.

Hypothetical shelter use among non-evacuees was greater than actual use among evacuees (36% in Warwick and 22% in Newport) (MR-Fig. 27). These hypothetical responses are typical of the overestimation normally observed when comparing intended to actual shelter use. It does, however, tend to reinforce the notion that dependence upon public shelters will be greater in Warwick. It's likely that *if* the stayers in Gloria had evacuated, 15% in Warwick and 10% in Newport would have attempted to go to public shelters.

Table 2, showing guidelines for projecting normal shelter demand, reflects these patterns. Late, urgent evacuations, which will roughly double normal shelter demand, are not a function of location. It should also be noted that emergency

Income	Risk Area: *High*	*Mod*	*Low*
High	5%	5%	10%
Med.	10%	15%	15%
Low	-	30%	30%

Note:

Figures will be higher if officials encourage use of public shelters.

Figures will be lower for developments with on-site shelters (e.g., clubhouses).

Figures will be lower where churches and other organizations shelter members.

Table 2. Evacuees going to public shelters: planning assumptions for Rhode Island.

management officials in some communities encourage shelter use more than others, and such policies should be taken into account in planning, because officials can take actions which either increase or decrease shelter use. Other factors to note are that retirees living in "retirement areas" are more likely to use public shelters than other groups, some communities have churches and other organizations which reduce "public" shelter use by being more active than normal in providing their own shelters, and some housing developments and mobile home parks provide onsite shelter which will alleviate demand for public shelter.

Evacuation Out-of-Town by Residents

Few of the people evacuating from either survey area went out-of-town: 31% in Warwick and 21% in Newport (MR-Fig. 30). Almost everyone in both locations said they required 30 minutes or less to reach their destinations, however, suggesting that evacuees travelled very short distances (MR-Fig. 31).

Differences are usually accounted for primarily by income (low income residents don't go as far), evacuation timing (late night, urgent evacuees don't go as far), and risk area (evacuees from high-risk beach areas go farther). Table 3 reflects these generalizations. Note too, that emergency management officials can influence this response. In some locations agencies have policies to discourage evacuees from staying in the local area. Communities which aggressively provide and publicize public shelters will have fewer evacuees leaving the local area.

Very Strong Storm, Early Evacuation			Weak Storm Typical Timing		
Risk Area			Risk Area		
High	*Mod*	*Low*	*High*	*Mod*	*Low*
65%	40%	10%	40%	30%	20%

Note:

Figures will be lower for low income and elderly retired evacuees.

Figures will be lower for last minute evacuations.

Figures will be higher if officials encourage evacuees to leave area.

Table 3. Percent of evacuees leaving local area: planning assumptions for Rhode Island.

Vehicle Use by Residents

The average number of vehicles used per evacuating household in Gloria was greater for Warwick (1.5) than Newport (1.2) (MR-Fig. 37). About 10% in both locations used no vehicles at all, probably walking short distances to friends or to shelters or riding with someone else (MR-Fig. 36).

Normally 65% to 75% of the vehicles available to a household are used in evacuations, and both Rhode Island survey locations fell within or near that range in Gloria (71% and 76%). **For planning purposes it would be reasonable to assume that approximately 70% to 75% of available vehicles will be used in most evacuations.**

No one in either sample said they required assistance from public agencies in evacuating (MR-Fig. 41), and no one said they used public transportation (MR-Fig. 38). Of those respondents who did *not* evacuate in Gloria, no one in Warwick but 8% in Newport said they would have needed agency assistance *if* they had evacuated (MR Fig. 42). Normally, however, even in communities where agencies prepare lists of people and addresses needing evacuation assistance, it is common to find that those people have already been provided for by friends and relatives when public vehicles arrive to collect them. About 5% of the stayers in both sites said they would use public transportation if they evacuated (MR-Fig. 40). Five percent of the stayers in Warwick and 11% in Newport said they had no cars of their own available (MR-Fig. 39).

APPENDIX C

Transportation Analysis Support Documentation

April 1995

RHODE ISLAND HURRICANE EVACUATION STUDY
Transportation Analysis Support Documentation

Prepared for:
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Rev.3.1

RHODE ISLAND HURRICANE EVACUATION STUDY

TRANSPORTATION ANALYSIS SUPPORT DOCUMENTATION

April, 1995

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SECTION ONE

INTRODUCTION

1.1 PURPOSE

The purpose of the Transportation Analysis is to estimate roadway clearance times for coastal Rhode Island communities and affected coastal communities in Bristol County, Massachusetts[1] under a variety of hurricane evacuation scenarios. Clearance time is defined as the amount of time required for all vehicles to clear the roadways after a regional or state level hurricane evacuation recommendation is disseminated to the public. During an evacuation, a large number of vehicles have to travel on a road system in a relatively short period of time. A number of different vehicle trips are possible, varying by trip origination, time of departure, and trip destination. The number of vehicle trips becomes particularly significant for an area such as Rhode Island's coast because its land areas are highly urbanized with many residents living near the immediate shore. The number of evacuating vehicles varies depending upon the intensity of the hurricane, actions taken by local authorities, and certain human behavioral response characteristics of the area's population. Motorists evacuating their homes and intermixing with traffic from people leaving work or traveling for other trip purposes can lead to significant traffic congestion and backups, ultimately delaying the evacuation.

The Transportation Analysis is one element of a much broader study entitled the Rhode Island Hurricane Evacuation Study (HES). The Rhode Island HES Technical Data Report presents the results of several technical analyses to provide emergency management officials with realistic data quantifying the major factors involved in hurricane evacuation decision-making. The technical data presented in the Study is not intended to replace the detailed operations plans developed by the State and communities. Rather, the data is intended to provide a framework within which each jurisdiction can update and revise hurricane evacuation plans and from which operation procedures and guides can be developed for future hurricane threats. Because the Transportation Analysis builds upon results from other analyses of the Study, in this report, reference is frequently made to information that is presented in the Technical Data Report (TDR).

A transportation modeling methodology and a roadway representation were developed for all coastal communities in Rhode Island and southeastern Massachusetts within the study area to conduct the analysis and estimate clearance times. This analysis establishes the clearance time portions of evacuation times. Clearance time is one component of the total time required for a regional hurricane evacuation to be completed. An additional time component, which considers the amount of time necessary for public officials to notify people to evacuate, must be combined with clearance time to determine the total evacuation time. More information on how decision-makers can use the results of this analysis is discussed in detail in Chapter Eight, Decision Analysis, of the TDR.

1.2 STUDY AREA

The study area for the Transportation Analysis includes the entire State of Rhode Island and Bristol County, Massachusetts as illustrated in Figure 1-1. Bristol County, Massachusetts is included as part of

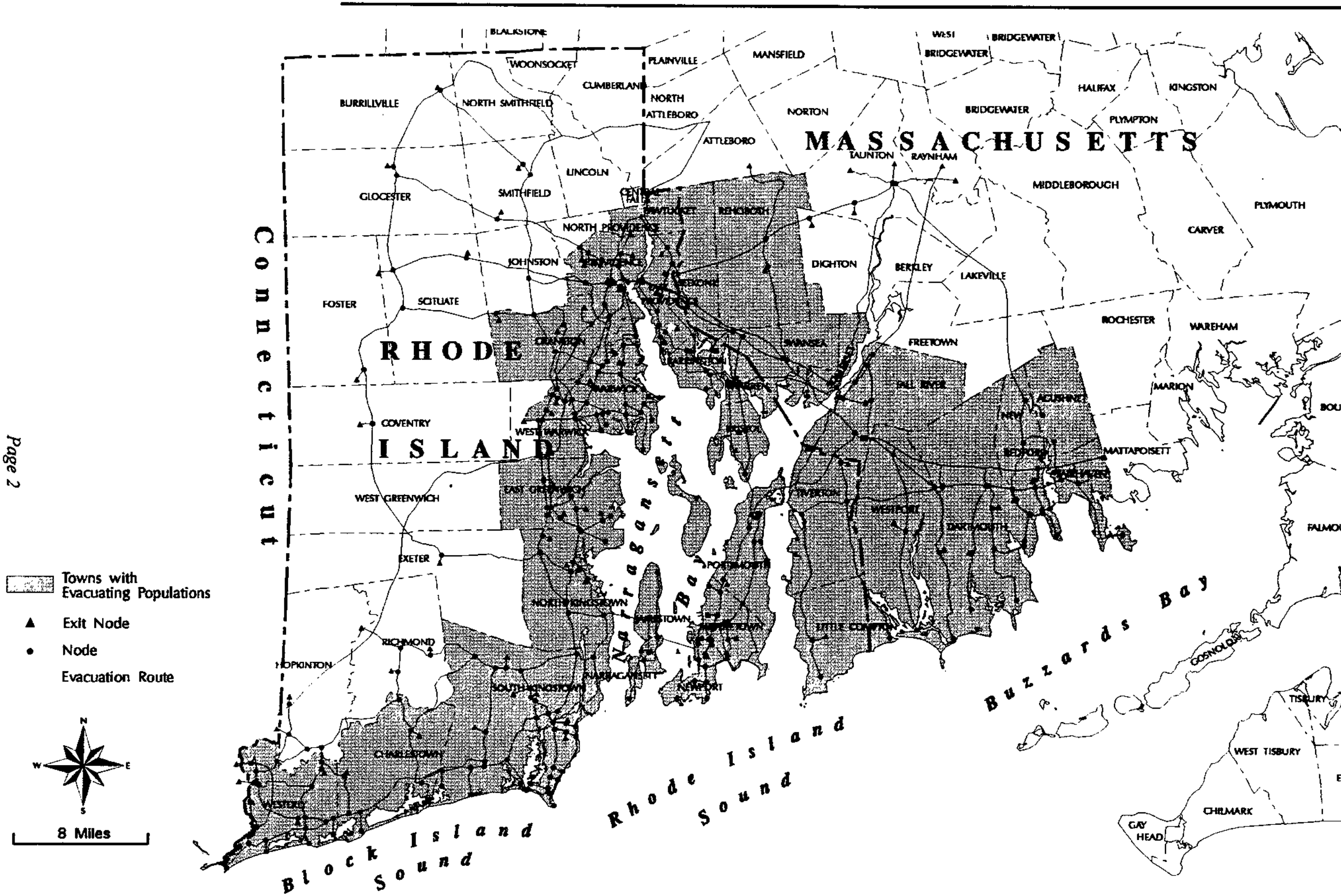

FIGURE 1-1: STUDY AREA

the Rhode Island Transportation Analysis because of the interdependence and inseparability of the eastern Rhode Island and southern Massachusetts roadway systems. The vastness of the Rhode Island and Bristol County, Massachusetts study area required that the region be divided into two approximately equal sized areas and analyzed individually. The two networks were defined as the "West Bay/Rhode Island Network" and the "East Bay/Massachusetts Network". The West Bay/Rhode Island Network extends from approximately the Connecticut-Rhode Island State Line eastward to Narragansett Bay. The East Bay/Massachusetts Network extends from approximately the Fairhaven-Mattapoisett, Massachusetts town line westward to Narragansett Bay.

The study area does not include the community of New Shoreham (Block Island) and Prudence Island. It is the intention of the community of New Shoreham and the Rhode Island Emergency Management Agency to evacuate all non-permanent residents from Block Island by ferry boat or other means possible in response to a hurricane threat. Currently, the Rhode Island Emergency Management Agency, in conjunction with the community of New Shoreham, is developing an Emergency Operations Plan which will include provisions for evacuating non-permanent residents from the Island. Shelter space will be provided on the island for permanent residents at an ARC Mass Care Facility located at the New Shoreham High School. No permanent residents live on Prudence Island.

The road system under examination includes major State maintained highways from the Connecticut state line to the Fairhaven-Mattapoisett, Massachusetts town line, extending approximately 15 miles inland from the coast. The analysis assumes evacuees originate from the various coastal communities and safe destinations include locations within coastal communities as well as locations farther inland, or in adjacent States. The Transportation Analysis was done at a state level, or macro scale, rather than at a community level because the intermixing of traffic from one community to the next was considered perhaps a leading contributor to delays in evacuations.

1.3 METHODOLOGY

The Behavioral Analysis discussed in Chapter Four of the TDR presents information about which destination types evacuees are most likely to choose during an evacuation in Rhode Island. The analysis concludes that people who evacuate surge areas are most likely to seek safe destinations at public shelters, friends'/relatives' homes, or hotels/motels. Although behavioral data provided in Chapter Four can give some guidance in predicting the actual geographic areas people will evacuate to and the evacuation routes people may use to reach their destinations, assumptions of this nature tend to be subjective. This is caused by the vast number of possible destinations and routes available to evacuees in highly populated areas. Clearance time calculations are further complicated by the affects of significant and varying amounts of "background" traffic that will be present on roadways as an evacuation progresses ("background" traffic refers to vehicle trips by people who leave work early and return home, people who travel through the region, and trips made by people preparing for the arrival of hurricane conditions or engaged in normal activities).

The study considered several approaches to estimate clearance times for the Rhode Island study area. The first approach considered was the one used by the Corps of Engineers and the FEMA to complete hurricane evacuation studies in the Gulf and southern Atlantic coast states. This approach assigns destinations and evacuation routes for the evacuating population by matching probable evacuee destinations (determined by a behavioral analysis) with the land uses known for the region. A mathematical model of the study area's roadway system is then used to calculate clearance times based on the trip distributions assumed for the evacuation. The time required for all evacuees to reach their predetermined destination is considered the clearance time. As reported in a post-hurricane assessment of Hurricane Hugo in 1989, the transportation analyses conducted for the North Carolina and South Carolina Hurricane Evacuation Studies were found to be very accurate in that the clearance times experienced during evacuations were very near predicted times. These results give evidence that this approach is accurate for study areas with limited alternative roadway systems and where adequate behavioral data and landuse information is suitable to identify evacuation routes and predict the destinations of evacuees. The following paragraphs explain some differences in the Rhode Island study area in comparison to other areas, and give the reasons why the Corps of Engineers employed an alternative transportation modeling approach for Rhode Island and Bristol County, Massachusetts.

One concern in using the transportation modeling approach discussed above for the Rhode Island study area was the appropriateness of assuming specific zonal evacuee destinations and evacuation routes. Inundation areas in Rhode Island and Bristol County, Massachusetts are relatively narrow, but densely populated. The complex system of interconnecting freeways, undivided state routes, and numerous local streets offer evacuees, and others on the roadways, many possible travel routes to reach their destinations. The region is generally characterized by diverse land uses in small geographic areas. Hotels and motels are sporadically located in most communities, friends' and relatives' homes could well be distributed over the entire area, and Rhode Island communities tend to open public shelters to accommodate their individual demands. The Study concluded that it was not practical to use the behavioral information developed for Rhode Island and Bristol County, Massachusetts to derive specific assumptions about evacuee destinations and evacuation routes. The study did conclude that the behavioral response curves presented in the Behavioral Analysis, and used in other hurricane evacuation studies, are useful when estimating the general response and destinations sought by residents who live in surge vulnerable areas.

The second concern in using the modeling approach used in other studies was the representation of the relationship between the number of people evacuating from vulnerable areas in comparison to the number of background vehicles that would be on the roadways during evacuations. Although surge areas are densely populated, the relatively small land areas that they encompass include only a fraction of the region's total population. When viewing the region's roadways as an entire transportation system, most of the traffic on roadways during initial and mid stages of an evacuation is likely to be from people leaving work early and from daily vehicles passing through the region. The problem during evacuations is that evacuating vehicles are forced to compete for roadway capacity with a larger amount of background traffic. This can cause increased congestion, potentially delaying the overall evacuation. Because background traffic will travel in both directions on nearly all roadways during evacuations, the Study determined that the transportation methodology for Rhode Island should not focus on assuming assigned evacuation routes as has been done in other study areas. Instead, the methodology should focus on analyzing the influence that background traffic can have on the overall evacuation.

To address the unique behavioral and transportation issues of the Rhode Island study area, an alternative modeling strategy was used. A mathematical model of the road system was developed and calibrated to simulate the traffic flows of a normal week day. Empirical traffic engineering studies and local traffic count data from the State's Department of Transportation (DOT) were used to establish various existing traffic flow conditions within the study area. The transportation modeling methodology used for this study assumes that the preferences of evacuees to travel on given routes are related to the traffic patterns of a normal day, except where it is clear that evacuees will travel directly to public shelters. The large portion of vehicles associated with background traffic enables the methodology to neglect assigning specific destinations and evacuation routes to evacuees traveling to hotels/motels and friends'/relatives' homes. Large business districts and confined hurricane surge areas in most coastal communities in Rhode Island and Bristol County, Massachusetts will give rise to evacuations involving mostly traffic generated by people leaving work rather than people evacuating surge areas. Analysis of traffic data collected on the days of Hurricanes Gloria and Bob further support this assumption. Accordingly, the modeling strategy used in the Rhode Island study focuses on estimating clearance times which qualitatively measure how competition by evacuating traffic may affect, and possibly delay, the movement of all traffic during an evacuation.

1.4 NETVAC2 TRAFFIC SIMULATION SOFTWARE

The NETVAC2 evacuation simulation software was used to create a mathematical model representing the study area's road system. NETVAC2 is a special purpose, network evacuation computer model designed by the Massachusetts Institute of Technology in cooperation with HMM Associates, Incorporated (now EARTH TECH). It was specifically designed to represent traffic flows over a transportation system during an emergency evacuation. This particular model was selected from several available models because it can be easily applied to model hurricane evacuations conducted in areas with complex roadway systems such as that in coastal Rhode Island and Bristol County, Massachusetts.

NETVAC2 represents roadways as links and intersections connecting two or more roadways as nodes. Physical characteristics about representative links and nodes, and the logic connecting them are inputs to the model used in computing vehicle capacity constraints and legal turning movements. Traffic flows at nodes are subject to intersection approach capacity constraints, whereas traffic flow assignments on outbound links are subject to the volume capacities of the modeled roads. Capacities are based on the Highway Capacity Manual (Highway Research Board) and Interim Material on Highway Capacity (Transportation Research Board).

A complementary program for use with NETVAC2, entitled POPDIS, converts the population that is assigned to enter onto roadways to an equivalent number of vehicles. The user enters the vehicle occupancy rates and the number of people assigned to enter the network at each node. As many as five different population types can be specified. POPDIS aggregates the population input for each entry node and in turn computes the effective average vehicle loading rate per minute at each node.

As vehicles are modeled to move throughout the road networks, NETVAC2 utilizes dynamic programming theory to update vehicle densities, speeds, flows, queues, spillbacks and other relevant traffic information at a fixed time step prescribed by the user. Traffic assignments from links entering and emanating nodes are made with each time step. One main feature of the model is that link assignments are made based upon the relative combinations of route preferences input for each node. The model also uses dynamic route selection such that route preferences are modified if significant backups exist at one or more emanating links. Vehicles preferring to travel on links undergoing heavy flows or large queues will be rerouted to another link of second preference. This is an important consideration when simulating hurricane evacuations because evacuees are not likely to wait in traffic for long periods of time if less restrictive, alternate routes are available to them.

Simulations terminate after vehicles exit the road system. NETVAC2 model results include computer print files of node and link time history flow and queue data, departing vehicle summaries, total simulation time, and total vehicles on the road system at specified report intervals.

SECTION TWO

MODEL DEVELOPMENT

2.1 GENERAL

The following sections discuss the coding assumptions made in applying NETVAC2 for modeling the hurricane evacuations in Rhode Island. The NETVAC2 User's Manual[2] gives specific data format instructions and a complete description of all parameters required by the model.

The Rhode Island DOT provided information for the roadway and intersection data used for model development. Roadway and intersection data was retrieved from printouts of state routes extracted from a study by Louis Berger Associates provided by the RI DOT[7]. The study contained detailed information such as the number of travel lanes and auxiliary lanes, lane widths, and intersection approach widths. The total length of each road segment was measured from a scaled map of the roadway network. Functional classification of routes and land use information are also listed. As networks were created, field surveys conducted at several locations verified that the modeling strategy and data input in the models were consistent with physical conditions.

2.2 ROAD NETWORKS

The NETVAC2 program allows networks with up to 500 links and 1000 nodes to be constructed. The vastness of the Rhode Island and Bristol County, Massachusetts study area required that the region be divided into two approximately equal sized areas and analyzed individually. The two networks were defined as the "West Bay/Rhode Island Network" and the "East Bay/Massachusetts Network". The West Bay/Rhode Island Network extends from approximately the Connecticut-Rhode Island state line eastward to Narragansett Bay. The East Bay/Massachusetts Network extends from approximately the Fairhaven-Mattapoisett, Massachusetts town line westward to Narragansett Bay. In the NETVAC2 model, roadways and intersections in the study area are represented by a link-node network as shown in Figures 2-1 through 2-9.

For each link, the actual number of lanes, lane widths, total roadway length in feet, roadway type, surrounding land use, and lateral clearances from roadside obstructions were entered into a computer link file. Values for roadway lateral clearances were input such that link capacities were not influenced by roadside obstructions except in cases where a particular link represented a highway bridge with a restrictive road shoulder. The logical turning movements from one link to the next and route preferences controlling traffic flow onto each link were also specified.

Single nodes were used to identify intersections of two or more undivided state roads, or to represent significant changes in roadway characteristics. Traffic flowing through intersections modeled using single nodes is forced to compete for the right of way with opposing traffic from other approaches. Major interchanges connecting divided and undivided highways, or connecting two undivided highways were modeled with four nodes per interchange. A greater number of nodes at these interchanges were needed to replicate non-opposing continuous traffic flow characteristic of highway on-ramps and off-ramps.

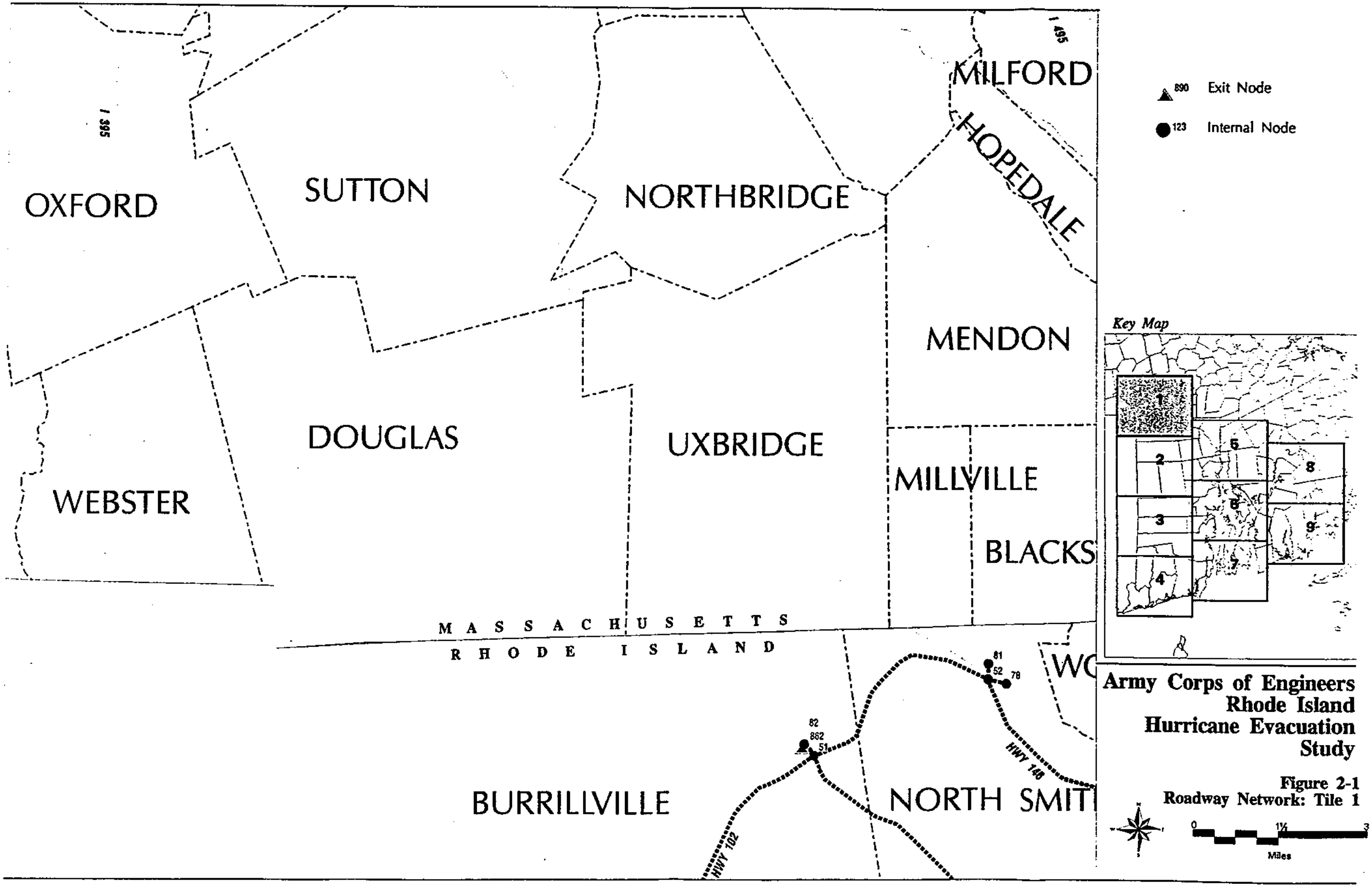

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Figure 2-1
Roadway Network: Tile 1

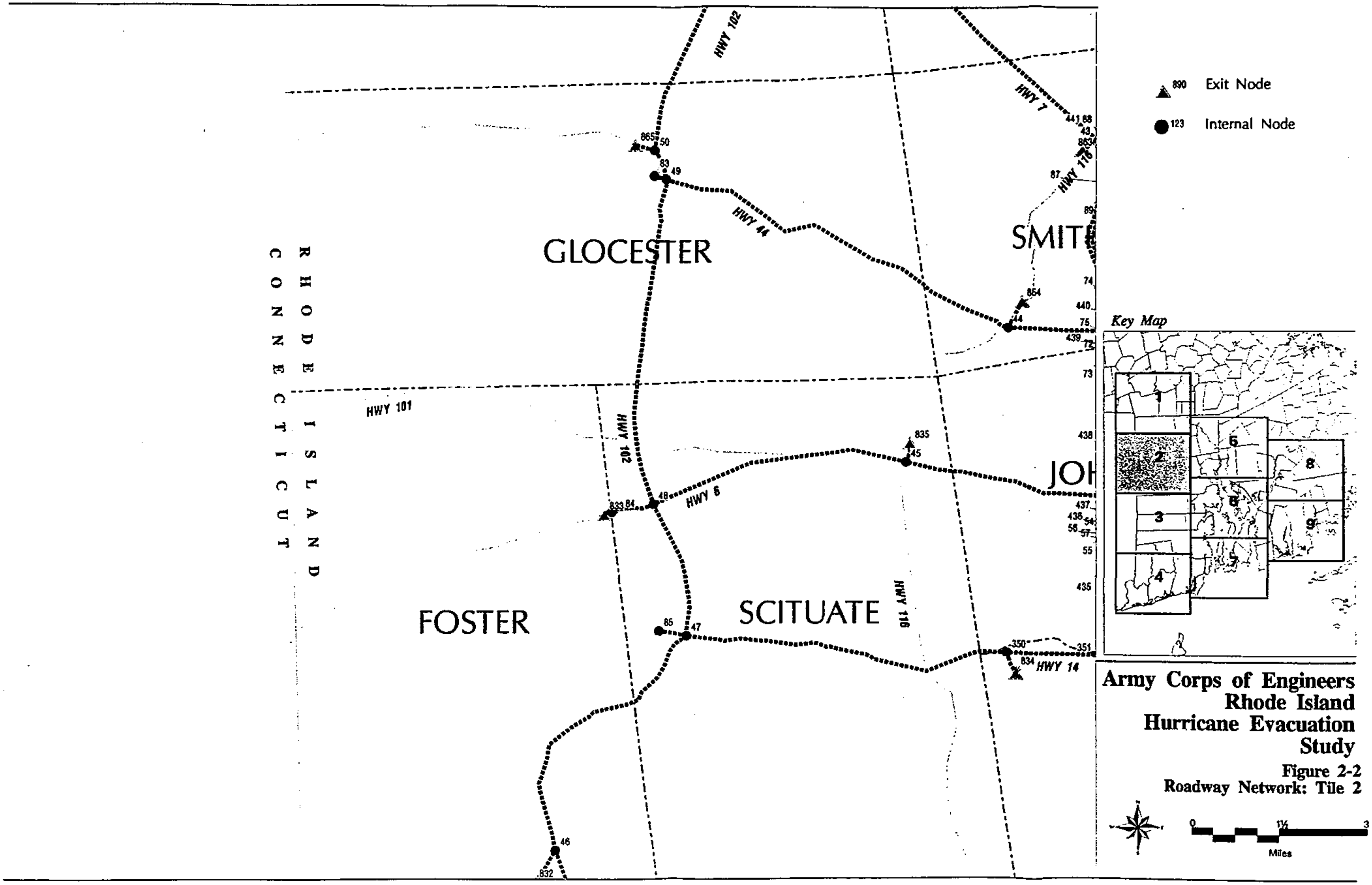

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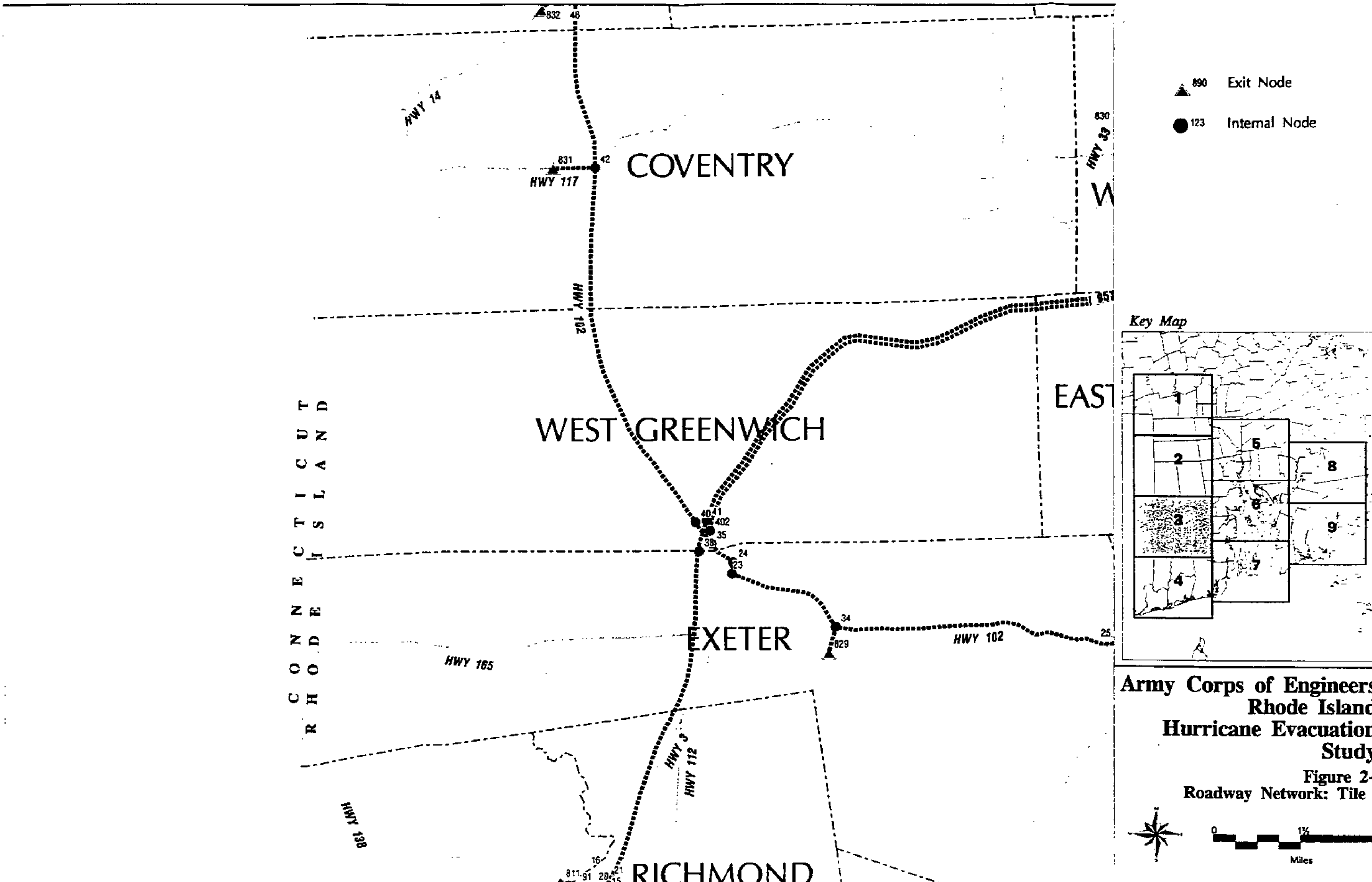
Figure 2-2
Roadway Network: Tile 2



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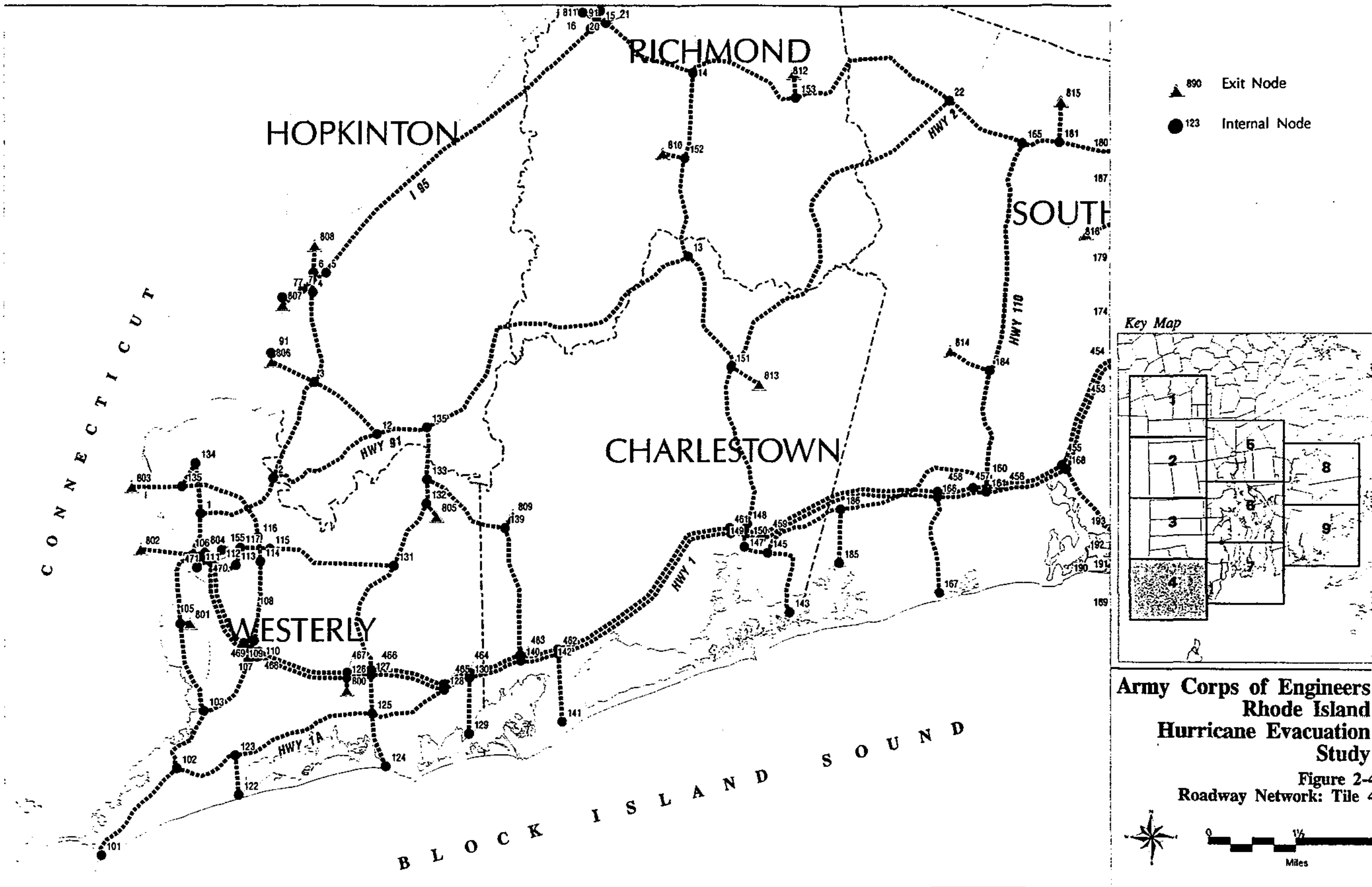
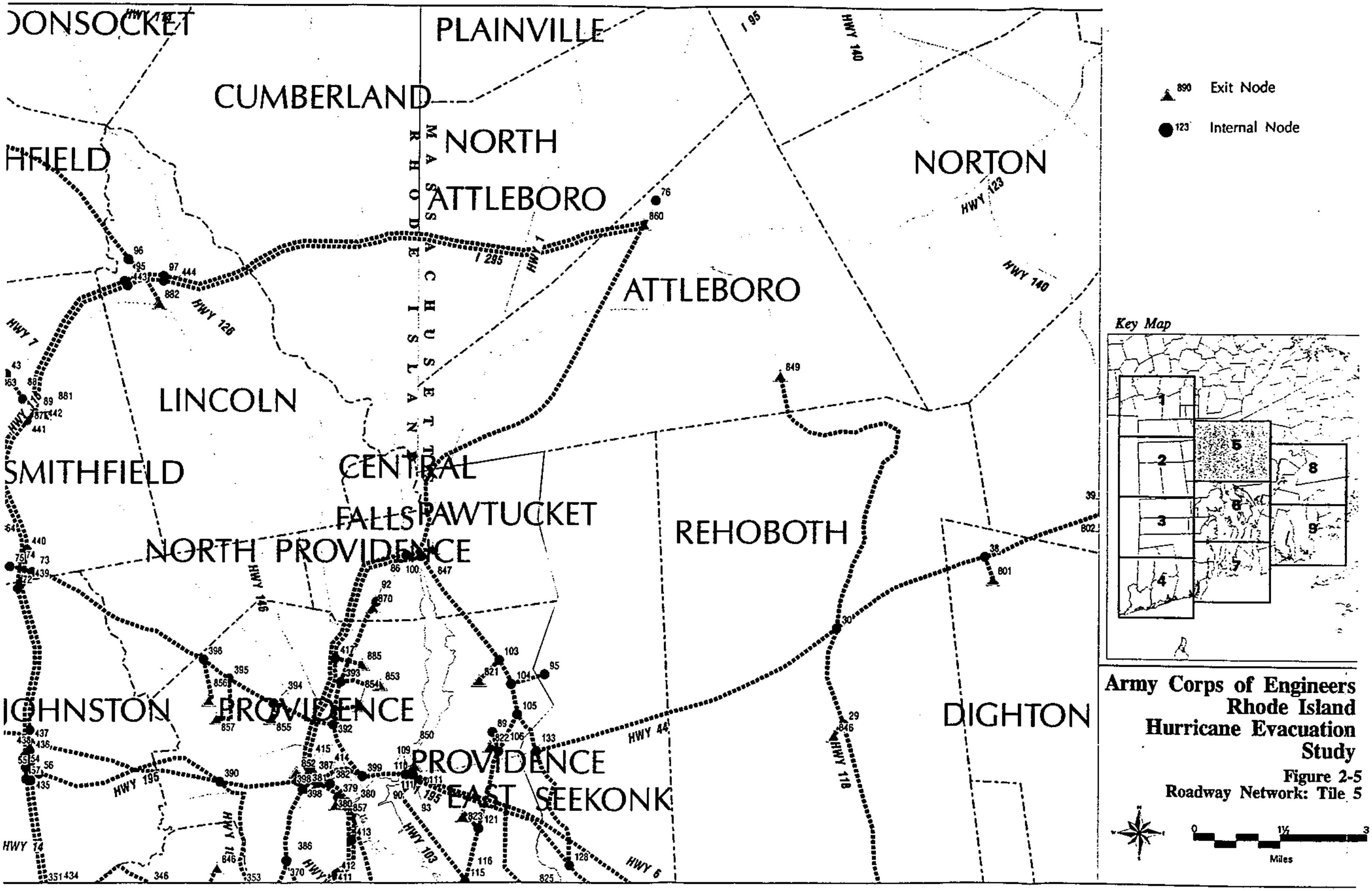
Hurricane Evacuation Study

Figure 2-3
Roadway Network: Tile 3



Army Corps of Engineers Rhode Island Hurricane Evacuation Study

Figure 2-4 Roadway Network: Tile 4



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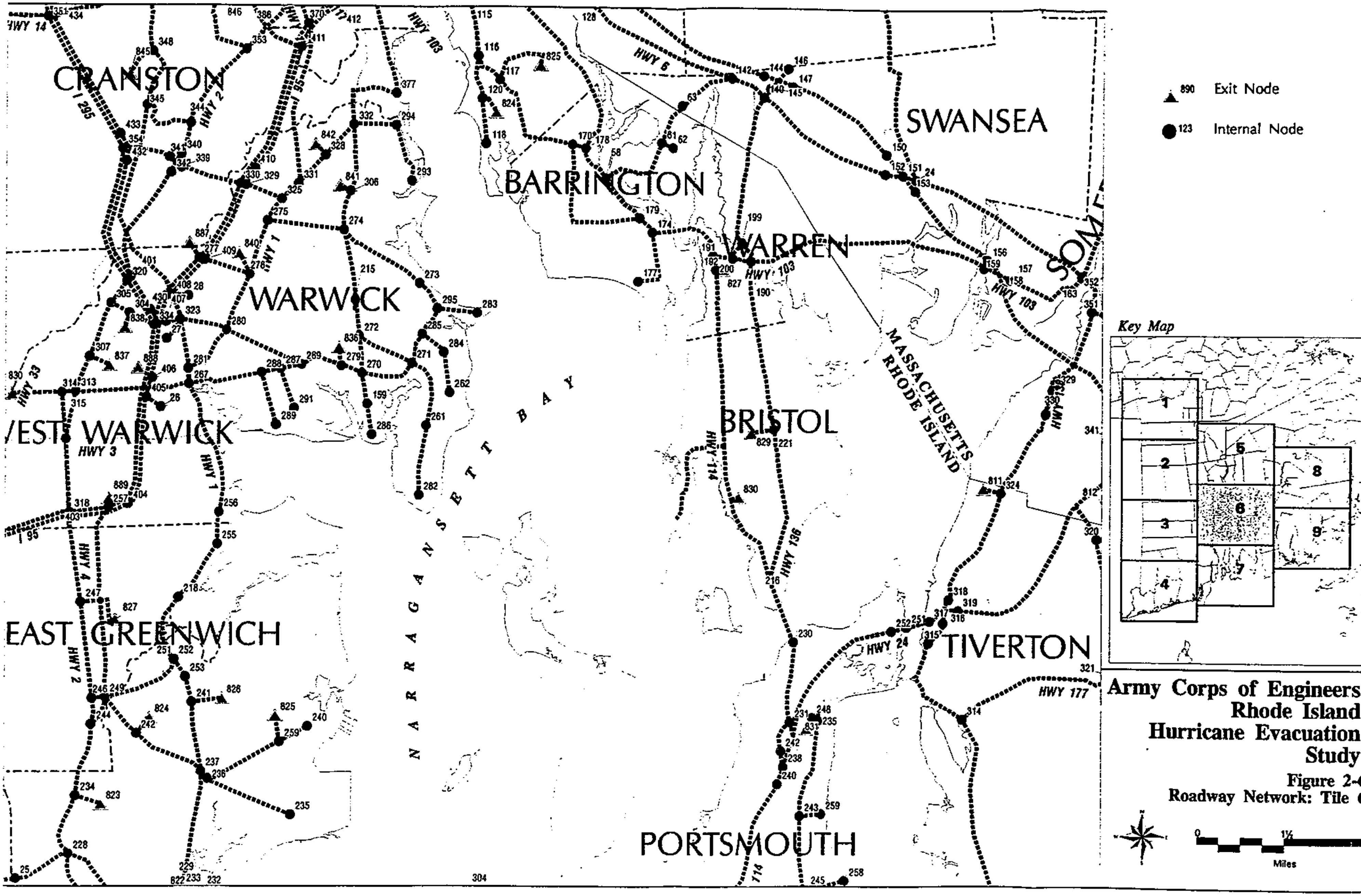
Rhode Island
Hurricane Evacuation
Study

Figure 2-5
Roadway Network: Tile 5



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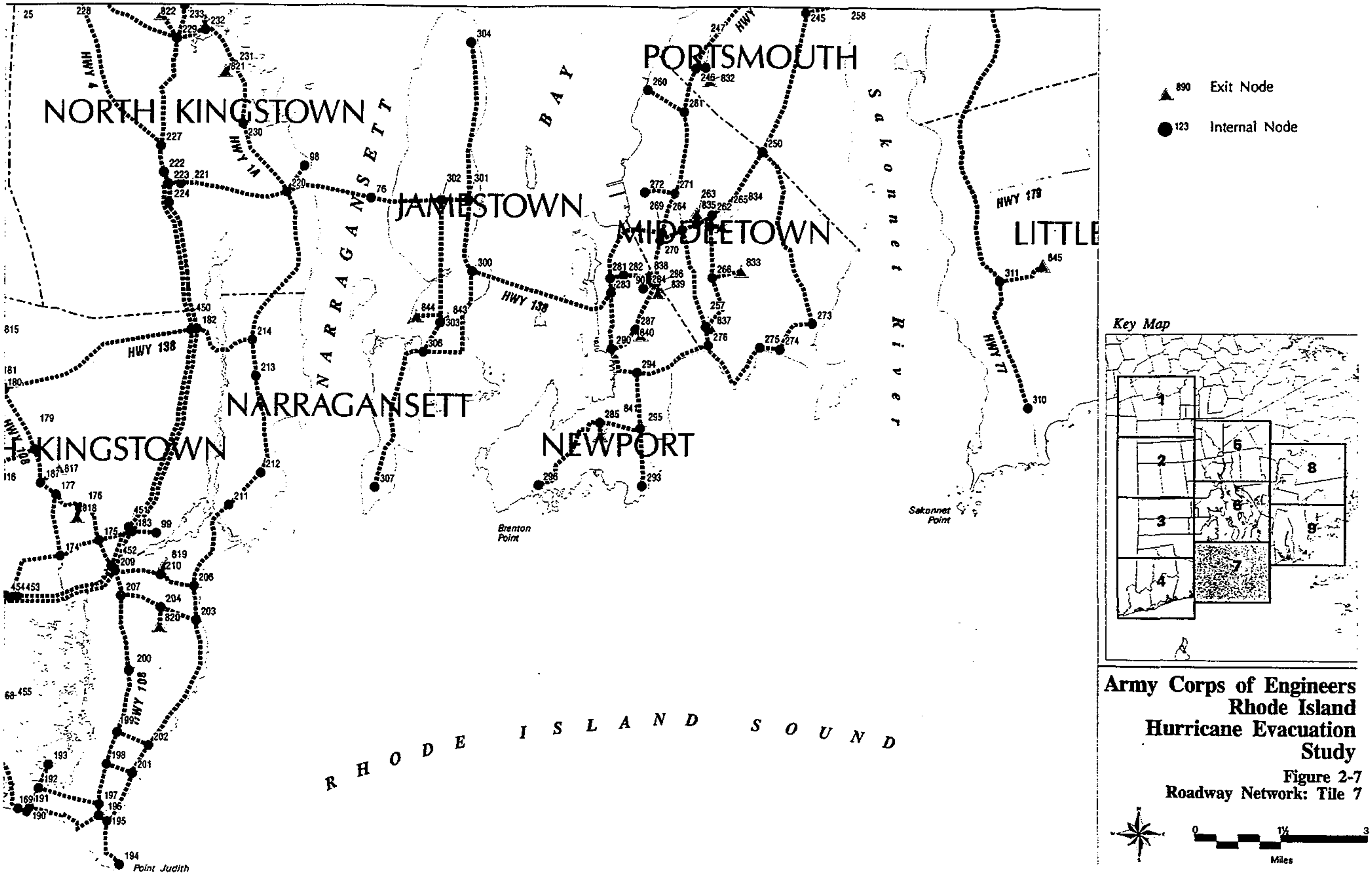
Rhode Island
Hurricane Evacuation
Study

Figure 2-6
Roadway Network: Tile 6



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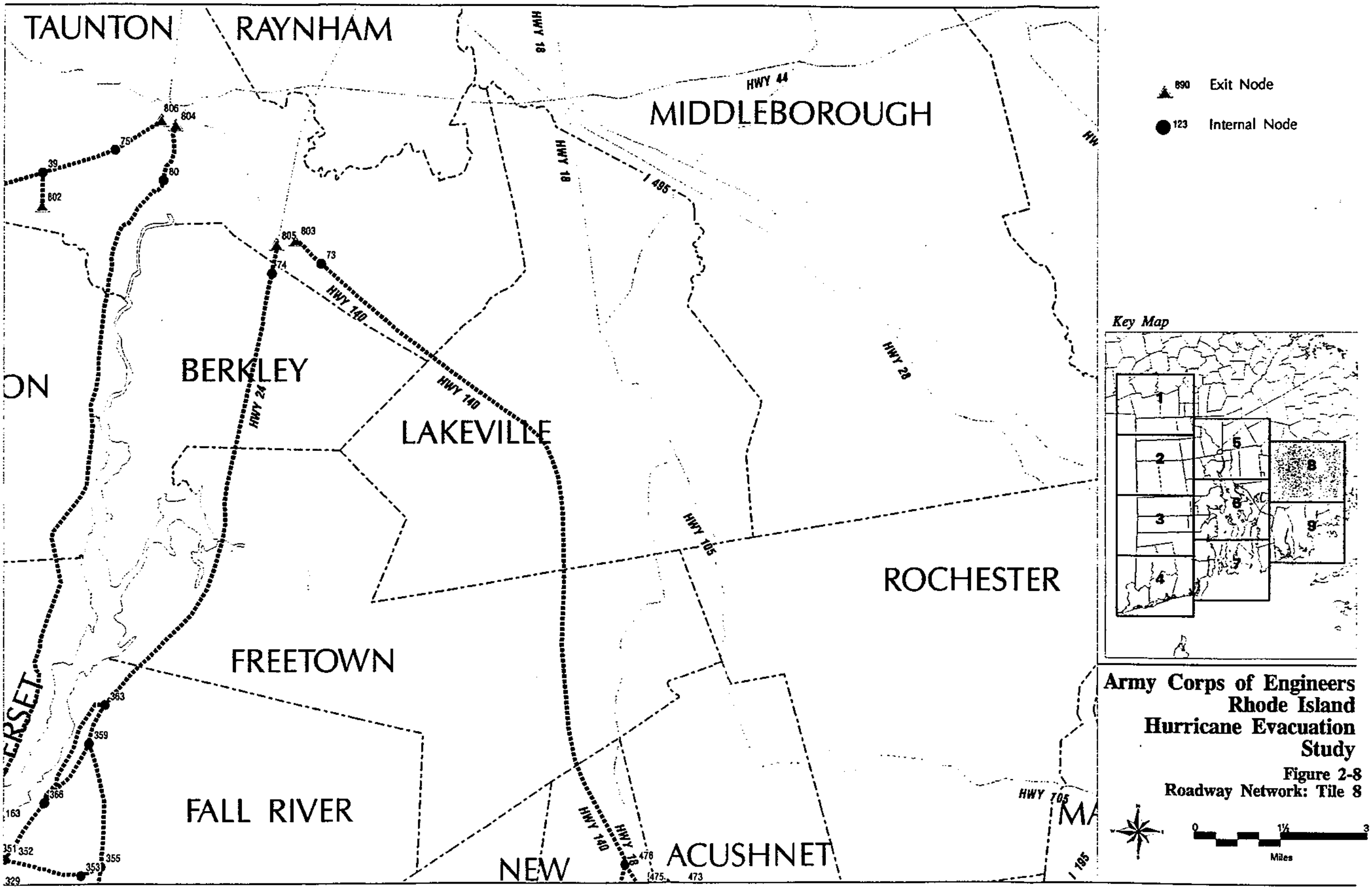
Hurricane Evacuation Study

Figure 2-7
Roadway Network: Tile 7



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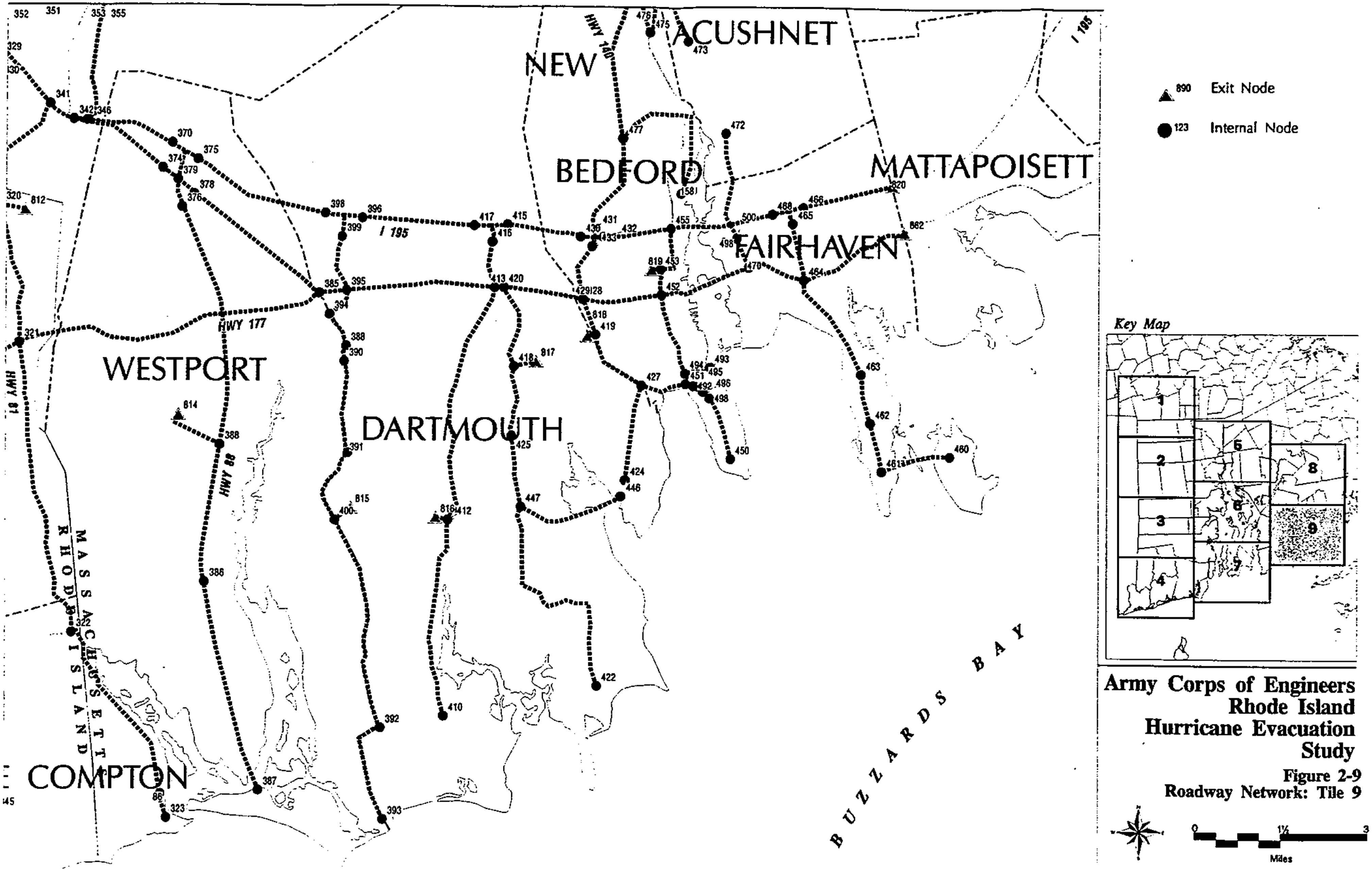
Rhode Island
Hurricane Evacuation
Study

Figure 2-8
Roadway Network: Tile 8



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Rhode Island
Hurricane Evacuation
Study

Figure 2-9
Roadway Network: Tile 9

Because areas along the immediate coast lack direct access to state routes, evacuees leaving these areas would first travel on local streets before entering onto state routes. Therefore, areas immediately along the coast, which do not have state routes passing nearby, were provided network access by links representing local streets. The information entered for these links idealized the capacities of several local streets rather than any particular street. The majority of evacuees were programmed to enter networks from local streets extending into coastal areas. However, some evacuees were assigned to enter directly onto the networks at nodes positioned along state routes near the coast.

As a starting point, intersection approaches were all initially coded as equal priority. Coding the model in this manner assumes that at signalized intersections the green time for a particular intersection approach is directly proportional to the relative amount of traffic volume from its approach, relative to the cumulative volume of traffic from all other approaches. In turn, this forces vehicles to compete for the right of way which is typical of normal traffic conditions. Accordingly, more green time is allotted to approaches with the highest volumes.

NETVAC2 allows vehicles to exit networks at specified nodes, designated as sink nodes. Exits were created within each study area's interior to represent locations of available public shelters (locations are illustrated by the squares in Figures 2-1 through 2-9).

The following presents the rationale used to develop an estimate of the general destinations of evacuees from study area communities. The report entitled Hurricane Evacuation Behavior in the Middle Atlantic and Northeast States (HEB Report) indicated the following:

- In the northeast, 55 to 79% of the evacuating population stay within their local town.
- In the northeast, between 83 and 100% of the evacuating population reach their destination in approximately 30 minutes.
- In the northeast between 3 and 23% of the evacuating population uses public shelters.

A second source, the Federal Emergency Management Agency (FEMA), has a standard for public sheltering capacity of 20%. A third source in determining the approach for this study was the actual shelter capacities in the affected communities. It was calculated that the vulnerable communities in total have capacity to shelter approximately 50 to 60% of the total evacuating population. Based on the above, the following approach for determining which exit nodes are assigned priorities was used:

- Assign 15% of the evacuating population to exit nodes corresponding to public shelters within the community (this is slightly higher than would be expected in the northeast but in line with the FEMA 20% planning basis).
- Assign an additional 40% of the evacuating population to exit nodes within the community from which they evacuate. Many of these exit nodes will be the same location as the public shelters. This brings the total evacuating population which stays within their

community up to 55% between public shelters and other destinations (consistent with the 55-79% which stay within their town).

- Assign 25% of the evacuating population to interior exit nodes outside the affected communities but within 15 miles of the coast (corresponding to 30 minute travel time). This brings the total within 30 minutes travel time up to 80% (slightly lower than with the 83-100% anticipated in the northeast but tends to be conservative).

- Assign 20% of the evacuating population to exterior exit nodes, roughly 15 miles or more from the inundation areas.

2.3 MODEL CALIBRATION

Before evacuation simulations were run, each network was first calibrated for its study area. Calibration is performed for two primary reasons. First, it establishes the route preferences that will be used by all vehicles during an evacuation simulation. Route preferences control the numbers of vehicles assigned to travel on each road. Second, calibration determines how many vehicles must be loaded at a given loading rate to achieve traffic patterns typical of a normal day. Before an evacuation takes place, the modeling methodology assumes traffic patterns of a normal day occur. Therefore, NETVAC2 was programmed to simulate normal traffic patterns at peak, mid-peak, and off peak conditions at the start of all model runs. Only after a hurricane threat becomes imminent, and people begin responding to warnings, are changes in normal day traffic anticipated. The following paragraphs describe how traffic counts recorded for average daily periods were used to calibrate each study area network.

Average Daily Traffic (ADT) volume data (i.e., 24-hour period) are collected along most state and interstate roadways in Rhode Island, by the Rhode Island Department of Transportation, and in Massachusetts by the Massachusetts Highway Department. In addition to the 24-hour counts, detailed hourly counts are conducted on a continuous basis at central stations in both Rhode Island[5] and Massachusetts[6].

The following sources of data were used to develop estimates of the existing, typical traffic volume levels along the study area roadways:

- "State Highway Map of Rhode Island, Traffic Flow Map", Rhode Island Department of Transportation, 1994 (showing 1993 Annual 24-hour Average Daily Traffic)

- "1993 Traffic Volumes for the Commonwealth of Massachusetts", Massachusetts Highway Department, 1994

- Automatic Traffic Counter Records (hourly summaries) for the following locations, from the Rhode Island Department of Transportation:

    - I-295 Southbound, Johnston
    - I-295 Northbound, Cumberland

- I-95 Northbound, Exeter
- I-95 Southbound, Exeter

- Route 1 Northbound, South Kingstown
- Route 1 Southbound, South Kingstown

- I-195 Eastbound, East Providence
- I-195 Westbound, East Providence

Hourly counts for I-195 in Dartmouth, MA were also obtained from the Massachusetts Highway Department[6].

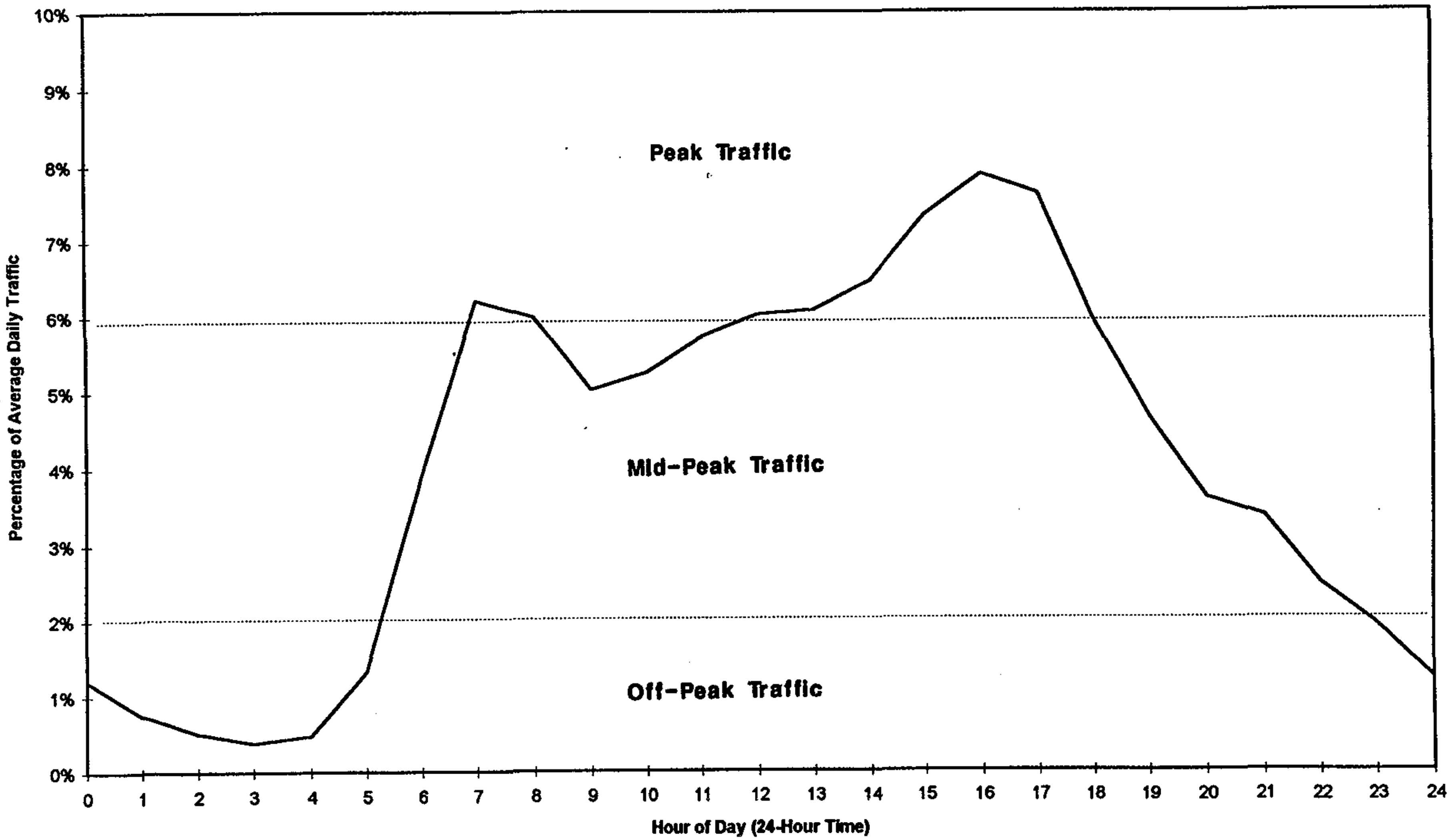
The distribution of ADT over a 24-hour period varies with each hour and day of the week. In general, the percentage of ADT is usually many times greater during peak traffic periods compared with times of off-peak traffic. Figure 2-10 plots weighted averages of the hourly weekday ADT volume recorded at traffic monitoring stations in Johnston, RI; Exeter, RI; South Kingstown, RI; East Providence, RI; and Dartmouth, MA. The distribution of hourly ADT at each location was found to vary in terms of magnitude, but overall trends and variations are generally similar.

In Figure 2-10, dashed lines delineate approximate levels of ADT corresponding to off-peak, mid-peak, and peak traffic. For the most part, off-peak traffic refers to light traffic volumes that typically occur late at night or in the early morning. Mid-peak traffic refers to moderate traffic conditions similar to that generally experienced in the late morning or early afternoon on weekdays, or on weekend days. Peak traffic represents the volume of traffic that is typical during weekday afternoon rush hour.

Although the distribution of ADT in Figure 2-10 may not reflect all of the local traffic patterns for each road in the study area, it does however provide a reasonable representation of how most of the vehicle trips in Rhode Island and Bristol County, Massachusetts are distributed over a normal day. Therefore, Figure 2-10 was used as a basis by which all the roadways within networks were calibrated.

For the final calibration tests, focus was placed on 31 key roadway links in Rhode Island and Southeastern Massachusetts to evaluate overall results. The actual unidirectional ADT at exterior nodes was entered as vehicles, and programmed to flow throughout each system. As simulation progressed, printouts every hour of simulation time reported the cumulative link departures and link speeds, as well as any spill backs and queues found at nodes. Calibration was accomplished using an iterative process of running NETVAC2, comparing modeled two-way ADTs to actual two-way ADTs for the 31 links, then adjusting link preference factors and adding traffic onto the network where appropriate before rerunning the model. During this process, a loading distribution that approximated average actual conditions was developed. The entire portion of major corridors such as I-95, I-195 and Route 1 were also reviewed in detail to ensure that the identified "check" locations were not isolated spots where ADT was correlated. The transportation methodology assumed calibration was complete when the volume of vehicles on each of the 31 links matched its corresponding actual two-way ADT by ±10% for Principal Arterials and 15% for Major Collectors[8], and the distribution of hourly traffic approximated actual conditions.

FIGURE 2-10: AVERAGE OF HOURLY ADT ALONG MAJOR ROUTES IN RHODE ISLAND AND BRISTOL COUNTY, MASSACHUSETTS



The results of the calibrated network analyses for these key links are represented in Tables 2-1 and 2-2, for the West Bay/Rhode Island and East Bay/Massachusetts networks.

TABLE 2-1: WEST BAY/RHODE ISLAND NETWORK CALIBRATION ANALYSIS

RHODE ISLAND NETWORK CHECKPOINTS

ROUTE	TOWN	ACTUAL ADT	MODELED ADT	% DIFFERENCE
14	Scituate	2,400	2,316	-4%
102	W. Greenwich/Coventry	4,100	4,633	+13%
2	Charlestown	4,300	4,482	+4%
6	Scituate	5,200	4,810	-8%
7	Smithfield	6,400	6,710	+5%
1	Charlestown	10,600	12,059	+14%
44	Glocester	10,800	12,446	+15%
1	East Greenwich/Warwick	16,100	17,246	+7%
1	South Kingstown	18,600	20,341	+9%
1	Westerly	20,600	17,831	-13%
295	Cumberland/N. Attleboro	29,600	27,690	-6%
95	Richmond/Exeter	34,100	37,504	+10%
295	Cranston	44,200	48,236	+9%
295	Johnston	51,400	48,132	-6%
195	Providence	60,300	58,066	-3%
95	Providence/N. Providence	120,600	112,231	-7%
95	Cranston/Providence	159,000	153,978	-3%

TABLE 2-2: EAST BAY/MASSACHUSETTS NETWORK CALIBRATION ANALYSES

SOUTHEASTERN MASSACHUSETTS NETWORK CHECKPOINTS

ROUTE	TOWN	ACTUAL ADT	MODELED ADT	% DIFFERENCE
114	Portsmouth	13,600	12,477	-8%
24	Portsmouth	19,600	19,769	+1%
77	Little Compton	2,800	2,795	0%
87	Tiverton	3,200	3,056	-4%
177	Westport	5,000	4,708	-6%
88	Westport	7,200	7,294	+1%
6	Dartmouth	16,000	14,462	-10%
195	Dartmouth	50,000	51,602	+3%
6	Fairhaven	28,000	28,640	+2%
195	Fairhaven	33,400	35,982	+8%
24	Berkley	30,000	32,088	+1%
138	Dighton	11,300	11,074	-2%
44	Taunton	16,000	15,320	-4%
195	East Providence	60,300	64,481	+7%

SECTION THREE

DEVELOPMENT OF TRAFFIC DATA

3.1 CLASSIFICATION OF MOTORISTS

After road networks were developed, the next steps of the analysis were to estimate the total number of vehicles that will load onto roadways, and determine the rates at which vehicles will load onto roadways over the course of an evacuation. To facilitate the development of this information, vehicles were classified as belonging to one of four major categories listed below:

(1) Surge Vulnerable Evacuees: Permanent and seasonal residents living in evacuation zones who evacuate when directed to do so by authorities.

(2) Non-Surge Vulnerable Evacuees: Permanent and seasonal residents, excluding mobile home residents, living outside evacuation zones who choose to evacuate. Most of the evacuees of this category leave their homes because of perceived dangers and not necessarily because of real flooding threats. However, in some cases, officials may deem it necessary to evacuate small groups of people who live in substandard housing units particularly vulnerable to hurricane winds, or those who live in or near areas that may be exposed to freshwater flooding.

(3) Mobile Home Evacuees: All permanent and seasonal mobile home residents of coastal communities. The analysis assumes all mobile home residents will be told to evacuate by local officials due of their high risk to strong winds from storms of even modest intensities.

(4) Background Vehicles: The population associated with all remaining vehicle trip purposes. Examples are: Trips made by people who leave work early and return home, people who travel through the region, and trips made by persons preparing for the arrival of hurricane conditions or engaged in normal activities. This traffic can also include transit vehicles (vans/buses) used to pick up evacuees without personal transportation.

The number of vehicles assumed to participate during an evacuation from each group listed is an important factor in estimating clearance times. Human behavioral information developed in Chapter Four, Behavioral Analysis, in the TDR, gives clear estimates of the participation that can be expected from the first three groups. The fourth group, Background Vehicles, is not addressed by the Behavioral Analysis. However, motorists belonging to this group mostly comprise of people making shopping trips or commuting, which is related to the ADT distribution shown in Figure 2-10.

For Rhode Island, Tables 3-1 and 3-2 list estimates made of the numbers of permanent and seasonal people who were assumed to evacuate their homes by population type for two levels of hurricane threat. Table 3-1 refers to evacuations for a weak hurricane scenario, and Table 3-2 gives similar estimates for a severe hurricane scenario. The same information for Bristol County, Massachusetts is provided in Tables 3-3 and 3-4. Estimates were made by applying evacuation participation behavioral assumptions to community population data (see TDR).

TABLE 3-1:
RHODE ISLAND EVACUATING POPULATION FOR A WEAK HURRICANE SCENARIO

Community	Permanent Population	Seasonal Population	Population Evacuating Mobile Homes	Population Evacuation Surge Areas	Population Evacuating Non-Surge Areas	Total Evacuating Population
Barrington	15,850	180	0	8,970	40	9,010
Bristol	21,630	400	20	2,980	330	3,330
Charlestown	6,480	4,010	330	1,330	160	1,820
Cranston	76,060	200	50	1,600	1,480	3,130
East Greenwich	11,870	60	110	720	210	1,040
East Providence	50,380	110	170	4,740	860	5,770
Jamestown	5,000	1,070	10	1,640	70	1,720
Little Compton	3,340	920	190	650	60	900
Middletown	19,460	240	450	840	350	1,640
Narragansett	14,990	4,850	10	6,080	220	6,310
New Shoreham	840	1,880	0	670	40	710
Newport	28,230	1,640	0	7,300	390	7,690
North Kingstown	23,790	630	540	5,240	330	6,110
Pawtucket	72,640	70	880	540	1,420	2,840
Portsmouth	16,860	1,380	1,080	4,280	230	5,590
Providence	160,730	330	90	490	3,200	3,780
South Kingstown	24,630	6,610	460	3,850	510	4,820
Tiverton	14,310	450	720	1,670	230	2,620
Warren	11,390	270	10	4,650	80	4,740
Warwick	85,430	900	210	17,840	1,150	19,200
Westerly	21,610	3,570	210	4,150	380	4,740
TOTALS	685,520	29,770	5,540	80,230	11,740	97,510

TABLE 3-2:
RHODE ISLAND EVACUATING POPULATION FOR A SEVERE HURRICANE SCENARIO

Community	Permanent Population	Seasonal Population	Population Evacuating Mobile Homes	Population Evacuating Surge Areas	Population Evacuating Non-Surge Areas	Total Evacuating Population
Barrington	15,850	180	0	12,500	110	12,610
Bristol	21,630	400	20	4,780	840	5,640
Charlestown	6,480	4,010	330	1,960	400	2,690
Cranston	76,060	200	50	2,050	3,700	5,800
East Greenwich	11,870	60	110	1,010	540	1,660
East Providence	50,380	110	170	6,530	2,150	8,850
Jamestown	5,000	1,070	10	2,130	190	2,330
Little Compton	3,340	920	190	870	160	1,220
Middletown	19,460	240	450	1,420	880	2,750
Narragansett	14,990	4,850	10	8,110	540	8,660
New Shoreham	840	1,880	0	760	90	850
Newport	28,230	1,640	0	9,530	960	10,490
North Kingstown	23,790	630	540	6,540	830	7,910
Pawtucket	72,640	70	880	600	3,560	5,040
Portsmouth	16,860	1,380	1,080	4,910	590	6,580
Providence	160,730	330	90	910	8,000	9,000
South Kingstown	24,630	6,610	460	4,970	1,260	6,690
Tiverton	14,310	450	720	2,130	580	3,430
Warren	11,390	270	10	6,760	210	6,980
Warwick	85,430	900	210	25,700	2,880	28,790
Westerly	21,610	3,570	210	5,960	960	7,130
TOTALS	685,520	29,770	5,540	110,130	29,430	145,100

TABLE 3-3
BRISTOL COUNTY, MASSACHUSETTS EVACUATING POPULATION
FOR A WEAK HURRICANE SCENARIO

Community	Permanent Population	Seasonal Population	Population Evacuating Mobile Homes	Population Evacuating Surge Areas	Population Evacuating Non-Surge Areas	Total Evacuating Population
Acushnet	9,550	30	570	0	160	730
Dartmouth	27,240	1,130	130	2,700	490	3,320
Fairhaven	16,130	1,150	50	3,850	100	4,000
Fall River	92,700	150	90	2,520	1,760	4,370
New Bedford	99,920	140	170	1,680	1,600	3,450
Rehoboth	8,660	50	10	410	160	580
Seekonk	13,050	50	0	330	250	580
Somerset	17,660	50	10	2,960	280	3,250
Swansea	15,410	170	10	4,270	210	4,490
Westport	13,850	1,830	90	1,550	270	1,910
	314,170	4,750	1,130	20,270	5,280	26,680

TABLE 3-4
BRISTOL COUNTY, MASSACHUSETTS EVACUATING POPULATION FOR A SEVERE HURRICANE SCENARIO

Community	Permanent Population	Seasonal Population	Population Evacuating Mobile Homes	Population Evacuating Surge Areas	Population Evacuating Non-Surge Areas	Total Evacuating Population
Acushnet	9,550	30	570	820	410	1,800
Dartmouth	27,240	1,130	130	3,200	1,230	4,560
Fairhaven	16,130	1,150	50	11,100	250	11,400
Fall River	92,700	150	90	4,370	4,400	8,860
New Bedford	99,920	140	170	17,710	4,010	21,890
Rehoboth	8,660	50	10	580	400	990
Seekonk	13,050	50	0	480	630	1,110
Somerset	17,660	50	10	3,320	700	4,030
Swansea	15,410	170	10	4,810	510	5,330
Westport	13,850	1,830	90	1,740	680	2,510
TOTALS	314,170	4,750	1,130	48,130	13,220	62,480

3.2 BEHAVIORAL RESPONSE OF MOTORISTS

Perhaps one of the most critical assumptions that must be considered when estimating clearance times is the timing at which evacuees load onto roadways. Behavioral data from research obtained from past hurricane evacuations show that mobilization and actual departures of the evacuating population occur over a period of many hours and sometimes several days[3]. For Rhode Island, evacuation simulations were tested for three evacuation rates that are summarized by the response curves in Figure 3-1. Behavioral response curves describe the percentages of the evacuating population who leave their homes and load onto roadways at hourly intervals relative to when an evacuation recommendation is disseminated to the public.

The behavioral response curves are intended to include the most probable range of public responses that will be experienced in a future hurricane evacuation. The rapid response curve depicts the quickest mobilization response by evacuating households. For analysis purposes, the rapid response curve includes two hours of response time occurring before the evacuation recommendation is disseminated to the public and four hours after it is disseminated. For the moderate response curve, three hours of response time is assumed before dissemination of the evacuation recommendation, and six hours after. The slow response curve includes four hours of response time before notification of the evacuation recommendation, and eight hours after. The public's response before evacuation accounts for people who choose to evacuate their homes before being directed to do so by authorities. Regardless of the behavioral response curve used, 85 percent of all people who will eventually leave their homes are assumed to leave after being directed to do so by officials. This is an important point because people's timeliness in responding to a hurricane evacuation is extremely dependent upon the aggressiveness of authorities to encourage them to leave[4].

3.3 VEHICLE USAGE

The behavioral analysis conducted for Rhode Island estimated that approximately 75 percent of the vehicles available to evacuees will be used during future evacuations[4]. For the most part, families usually evacuate using one vehicle for fear of separation, but some households evacuate using two or more vehicles depending upon how many are available to them. Differences in vehicle ownership may vary with variations in access to public transportation, household income, and other socio-economic characteristics of the region.

The first column of Table 3-5 list permanent population by community. The second and third columns list the numbers of available vehicles per owner and renter - occupied housing units, respectively. This information was obtained from socio-economic data reported in the 1980 census[9]. The fourth column of the Table gives the number of available vehicles per person, and the fifth column gives the calculated average numbers of people that will travel in each evacuating vehicle, assuming 75 percent of the available vehicles are used. Similar information for Bristol County, Massachusetts is provided in Table 3-6. A sample calculation of the assumed persons per evacuating vehicle for Westerly, Rhode Island is shown below.

FIGURE 3-1: BEHAVIORAL RESPONSE CURVES

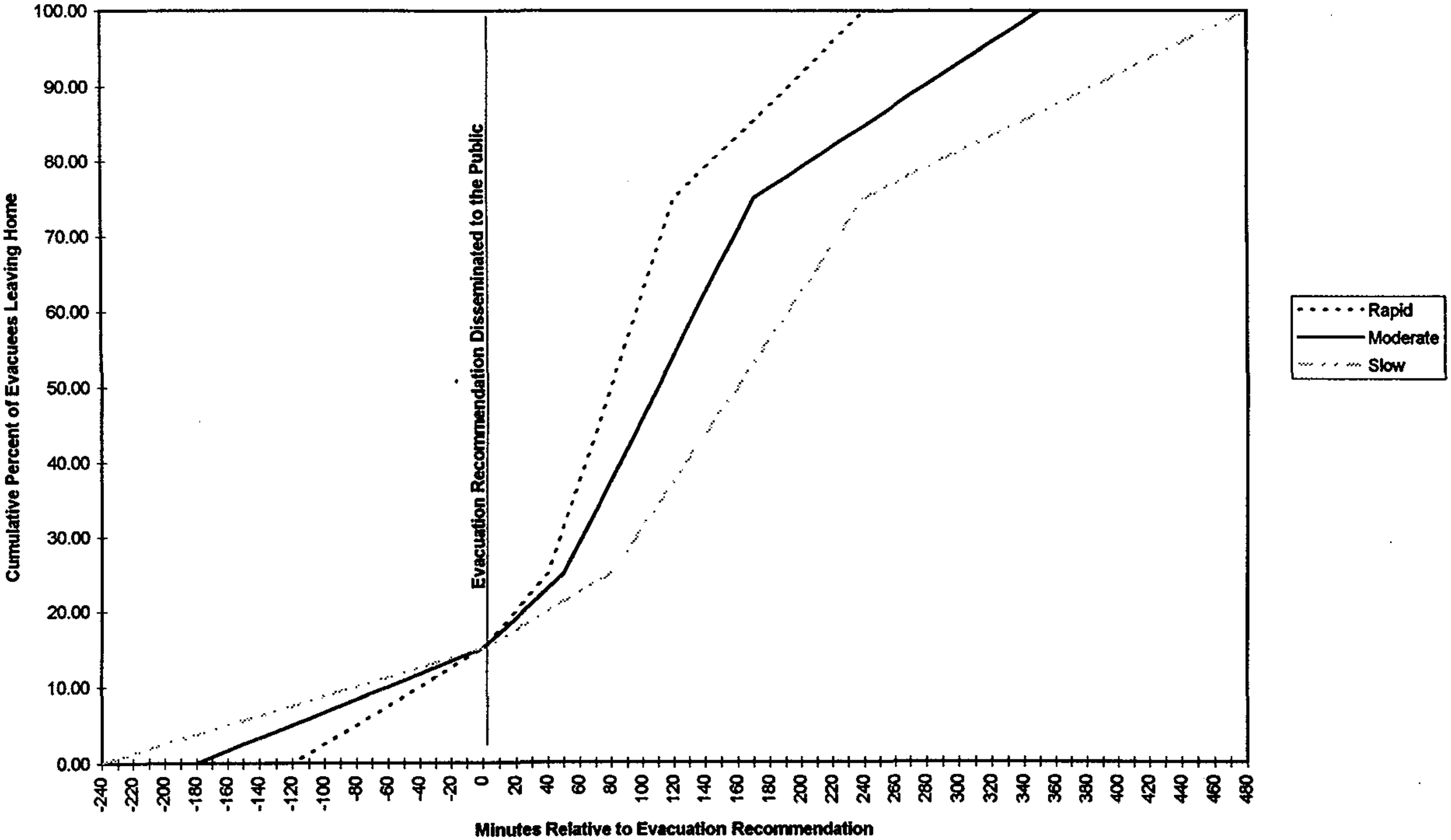


TABLE 3-5:
ASSUMED VEHICLE USAGE RATES BY COMMUNITY (RHODE ISLAND)

Community	Permanent Population	Available Vehicles in Owner Occupied Housing Units	Available Vehicles in Renter Occupied Housing Units	Vehicles Per Person	Persons per Evacuating Vehicle (75% Usage)
Barrington	15,850	10,400	890	0.71	1.88
Bristol	21,630	9,970	3,670	0.63	2.12
Charlestown	6,480	3,790	1,020	0.74	1.80
Cranston	76,060	37,370	12,210	0.65	2.05
East Greenwich	11,870	7,300	1,230	0.72	1.85
East Providence	50,380	22,500	9,240	0.63	2.12
Jamestown	5,000	3,240	730	0.79	1.69
Little Compton	3,340	2,250	490	0.82	1.63
Middleton	19,460	6,220	5,060	0.58	2.30
Narragansett	14,990	7,010	4,520	0.77	1.73
New Shoreham	840	540	240	0.93	1.43
Newport	28,230	8,140	8,020	0.57	2.34
North Kingstown	23,790	13,560	3,690	0.73	1.83
Pawtucket	72,640	24,430	18,410	0.59	2.26
Portsmouth	16,860	9,290	2,850	0.72	1.85
Providence	160,730	35,470	37,140	0.45	2.96
South Kingstown	24,630	10,900	3,380	0.58	2.30
Tiverton	14,310	9,230	1,360	0.74	1.80
Warren	11,390	5,080	2,390	0.66	2.02
Warwick	85,430	49,670	10,760	0.71	1.88
Westerly	21,610	10,500	4,530	0.70	1.90

TABLE 3-6
ASSUMED VEHICLE USAGE RATES BY COMMUNITY (MASSACHUSETTS)

Community	Permanent Population	Available Vehicles in Owner Occupied Housing Units	Available Vehicles in Renter Occupied Housing Units	Vehicles Per Person	Persons per Evacuating Vehicle (75% Usage)
Acushnet	9,550	5,820	690	0.68	1.96
Dartmouth	27,240	13,970	2,180	0.59	2.26
Fairhaven	16,130	7,840	2,290	0.63	2.12
Fall River	92,700	20,450	24,590	0.49	2.72
New Bedford	99,920	27,130	19,430	0.47	2.84
Rehoboth	8,660	5,730	520	0.72	1.85
Seekonk	13,050	8,730	820	0.73	1.83
Somerset	17,660	10,800	1,540	0.70	1.90
Swansea	15,410	9,930	800	0.70	1.90
Westport	13,850	8,510	1,480	0.72	1.85

Permanent Population	= 21,610 people	
Available vehicles	= 10,500 + 4,500	= 15,030 vehicles
Vehicles per person	$= \dfrac{15{,}030 \text{ vehicles}}{21{,}610 \text{ person}}$	$= 0.70 \dfrac{\text{vehicles}}{\text{person}}$

Persons per evacuating vehicle, assuming 75% usage

$$\frac{1}{0.70 \text{ vehicles/person} \times 0.75}$$

$$= 1.90 \text{ persons per vehicle}$$

The transportation methodology used the information in Table 3-5 and 3-6 to determine the vehicles that would load onto roadways during evacuations. The user enters the vehicle occupancy rates and the number of people assigned to enter the network at each node. NETVAC2's complimentary program, POPDIS, aggregates the population input for each entry node and in turn computes the effective average vehicle loading rates per minute to be input into NETVAC2 at network entry locations.

SECTION FOUR

EVACUATION SCENARIOS

Since all hurricanes differ from one another in some respect, it becomes necessary to set forth clear assumptions about storm characteristics and evacuees' expected response before transportation modeling can begin. Not only does a storm vary in its track, intensity and size, but also in the way it is perceived by residents in potentially vulnerable areas. These factors cause a wide variance in the behavior of the vulnerable population. Even the time of day at which a storm makes landfall influences the time parameters of an evacuation response. The transportation analysis computes clearance times based on sets of assumed conditions and behavioral responses. It is likely that an actual storm will differ from a simulated storm for which clearance times are calculated in this report. Therefore, key input parameters were varied to derive a range of evacuation scenarios idealizing many possible situations officials may have to contend with. The three major parameters that were varied with each simulation are described below.

(1) Hurricane Severity: Storms are classified as either weak or severe hurricanes. Evacuating population estimates (see Tables 3-1 through 3-4) are significantly greater (approximately double) for an evacuation due to severe hurricanes when compared with that for weak hurricanes. Category 5 hurricanes were not considered because the cooler waters of the Northeast can not sustain hurricanes of this intensity.

(2) Behavioral Response: The time in which evacuees mobilize to leave their homes and enter onto the roadway system is characterized by the behavioral response curves shown in Figure 3-1. Behavioral response curves are defined for rapid, moderate, and slow responses.

(3) Background Traffic Condition: The traffic condition at the start of an evacuation will depend upon the time of day the evacuation begins as well as other factors that may influence initial traffic conditions. As the NETVAC2 models were run, initial traffic conditions corresponding to off-peak, mid-peak, and peak ADT levels were analyzed. Figures 4-1a through 4-1c illustrate background vehicle distributions assumed for the following three conditions.

a. **Off-peak**: The off-peak traffic condition refers to light traffic volumes that typically occur late at night or in the early morning.

b. **Mid-peak**: The mid-peak traffic condition refers to moderate traffic conditions similar to that generally experienced in the two hour period occurring before and after the AM and PM peak conditions.

c. **Peak**: The peak traffic condition replicates the "rush hour" volume of traffic that is typical of the two hour period from 4:00 - 6:00 PM.

As noted above, background vehicles refer to motorists who travel roadways during an evacuation with trip purposes other than for evacuating their homes. At the start of an evacuation, the number of background

Figure 4-1a: Off-Peak Background Traffic Distribution

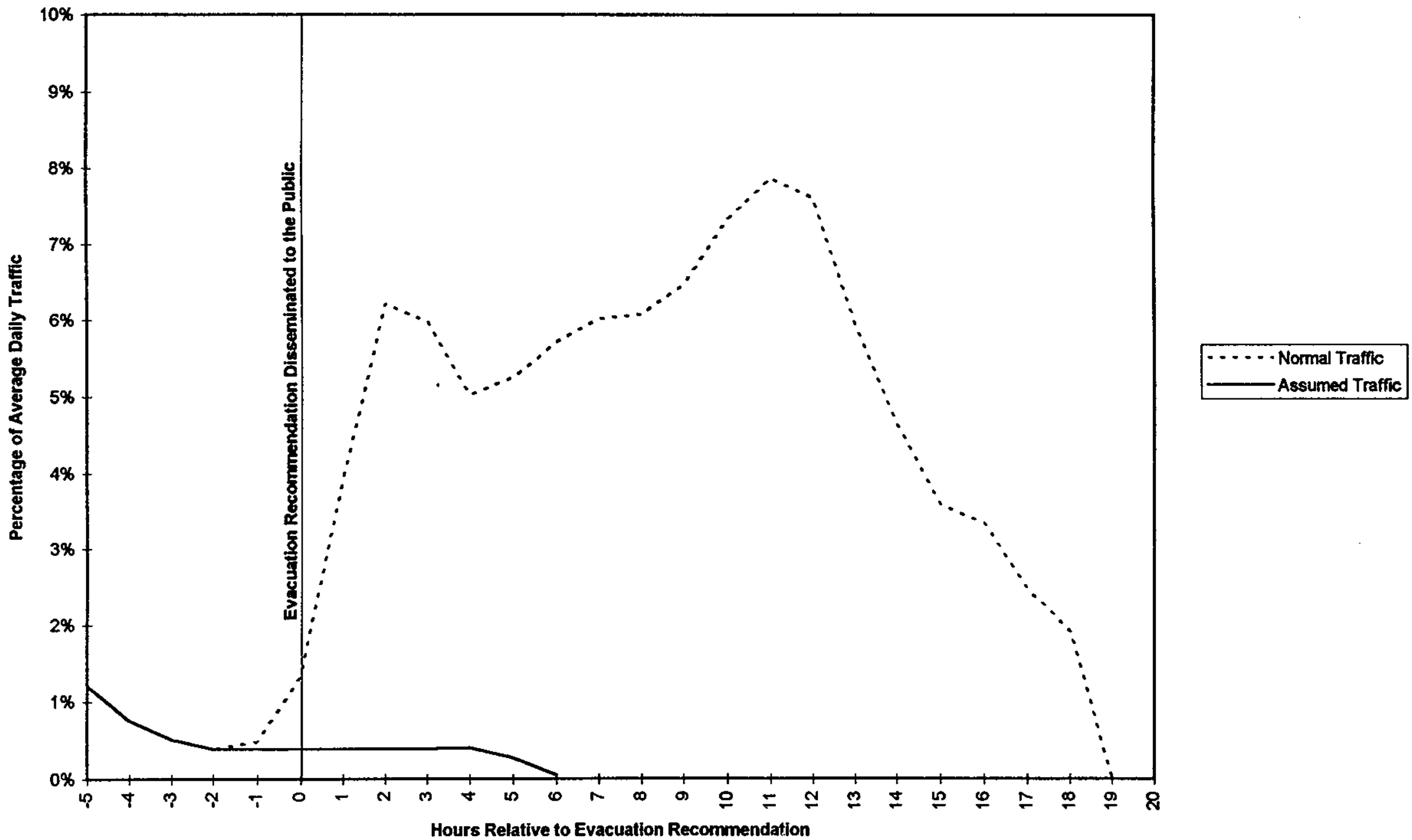


Figure 4-1b: Mid-Peak Background Distribution

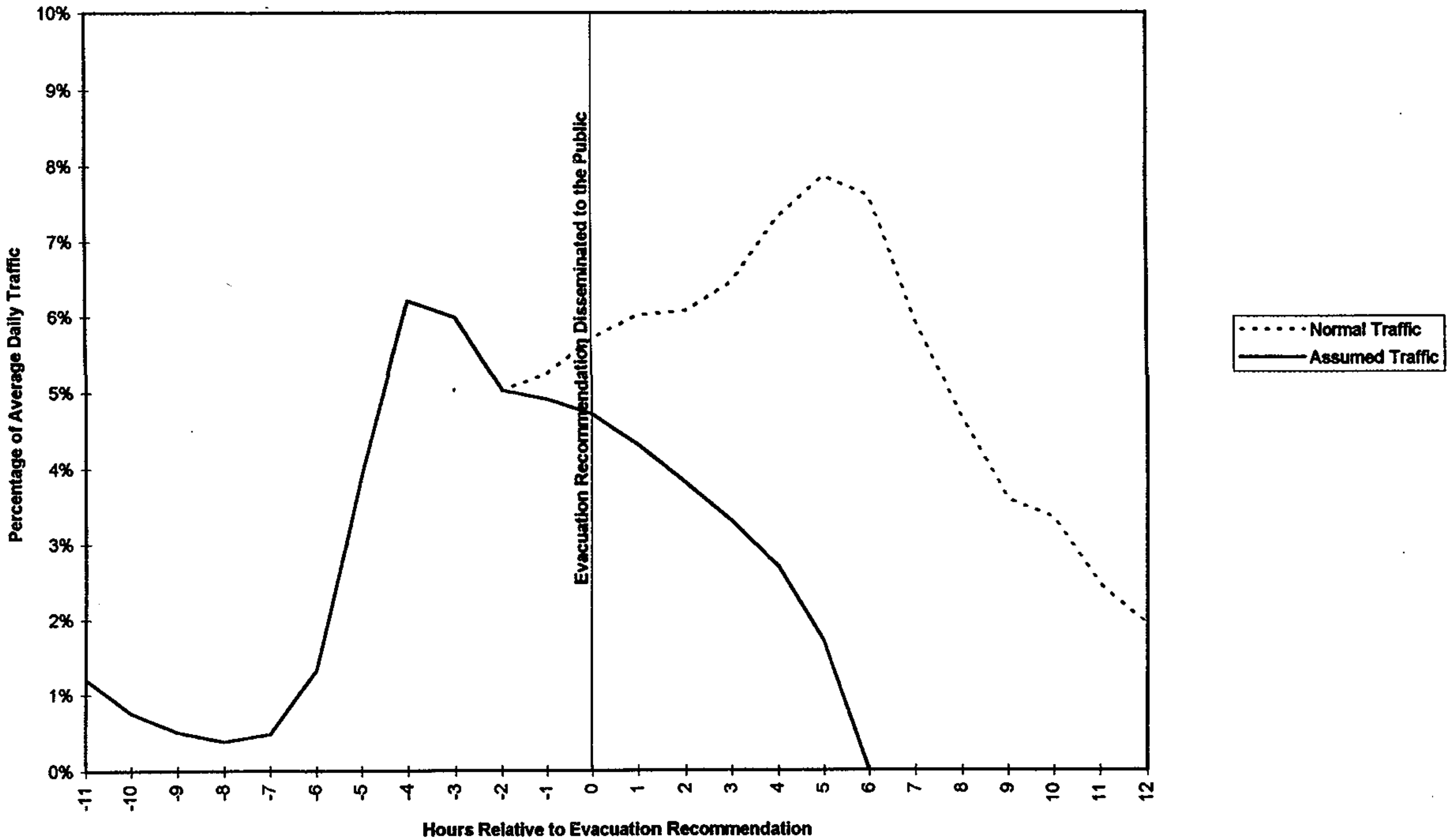
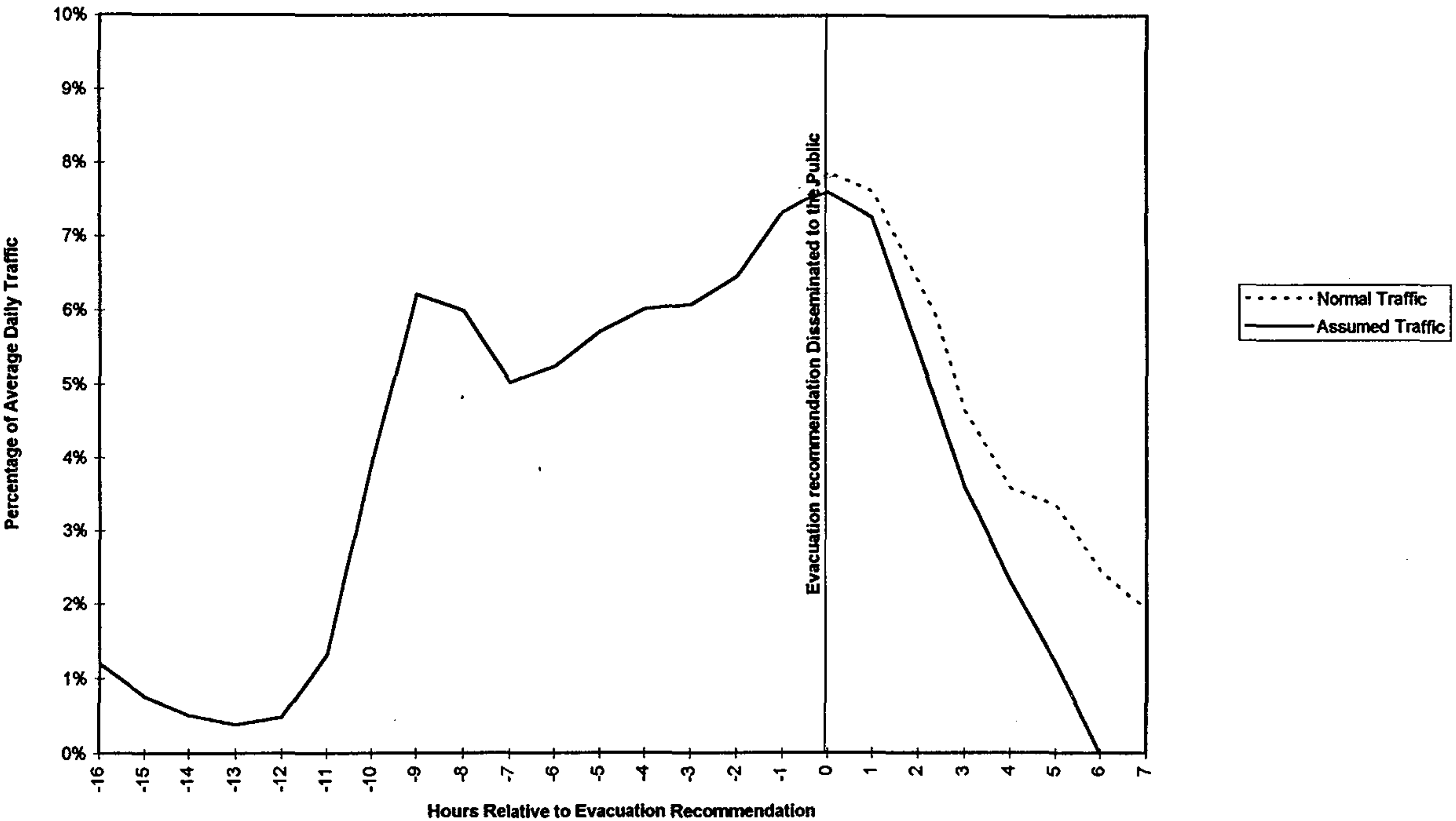


Figure 4-1c: Peak Background Distribution



vehicles assumed to exist on a particular road was taken as the ADT for that road on a normal day. As an evacuation progressed, the initial ADT assumed was slowly decreased until approximately zero background vehicles were on the roads at the completion of the evacuation.

Referring to the ADT distribution shown in Figure 2-10, the Transportation Analysis simulated evacuations occurring coincident with rush hour by programming evacuees to load onto roadways that were initially set at peak ADT volumes. Conversely, an evacuation occurring at times of light traffic, such as late at night or in the early morning, was modeled by running the model with background vehicles initially set at off-peak ADT volumes. Simulations run with background traffic at mid-peak ADT volumes represented moderate traffic volumes typical of mid-morning and mid-afternoon on weekdays or weekends.

The Transportation Analysis assumed the background traffic distributions shown in Figures 4-1a through 4-1c to apply to evacuations assuming a moderate behavioral response by evacuees. Background traffic distributions used for evacuations assuming a rapid or a slow behavioral response (not shown) follow the same curves shown in Figures 4-1a through 4-1c. The only exception is that evacuees are programmed to load onto roadways slightly before or after background traffic starts its decline. The number of background vehicles on any roadway during a a model run will vary depending upon each road's particular ADT and the hourly percentage of ADT assumed for the traffic condition modeled. A key point in using Figure 2-10 to derive background traffic conditions is that all traffic conditions are derived from actual traffic patterns observed for Rhode Island and Bristol County, Massachusetts rather than assumed hypothetical conditions.

Combinations of these key input parameters were used in developing 18 possible scenarios. For each of the networks, simulations were run for evacuations assuming weak hurricanes and severe hurricanes. Initial traffic conditions imparted on the road network followed the background distributions for off-peak, mid-peak, and peak traffic. Evacuees entered road networks at prescribed time intervals defined by the rapid, moderate, and slow behavioral responses.

Seasonal resident population and transient population visiting the area (i.e., tourism) varies widely in the study area, based upon the time of year, weather conditions, etc. The evacuating population used during simulations included seasonal residents as estimated from the 1990 census[10] from seasonal housing unit information. Coastal Rhode Island's seasonal population was found to be less than 12 percent of its permanent population. Although the varying transient conditions were not specifically evaluated for all scenarios, they were inherently addressed in a sensitivity analysis which focused on an evaluation of varying increases in study area population (refer to Section 5.3).

SECTION FIVE

ANALYSIS

5.1 GENERAL

Clearance time and dissemination time are two major considerations in deciding when an evacuation recommendation should be issued. The combination of these times defines a region's total evacuation time. Clearance time begins when an evacuation recommendation is clearly disseminated to the threatened public, and ends when the last evacuees clear the road system. This time includes the time required by evacuees to secure their homes and prepare to leave (mobilization time), the time spent by evacuees traveling along the road network (travel time), and the time lost due to traffic congestion (queuing delay time). Clearance time *does not relate solely to the time any one vehicle spends traveling on the road system.*

Dissemination time is the amount of time required by officials to notify the public to evacuate after the decision has been made. These values may differ by region depending on the communication and warning procedures utilized by State and local officials in their areas, and can best be estimated by the responsible state and local officials. The times calculated by the Transportation Analysis include only the clearance time component of evacuation time, and officials using this information must determine the dissemination time appropriate for their areas. Failure to add dissemination time to clearance time will underestimate total evacuation time, which could result in insufficient time for all evacuees to safely clear the hazard area.

Evacuations should be completed before the arrival of gale force winds (34 knot/39 mph) and/or storm surge. Vehicle accidents and reduced travel speeds from inclement weather can impede traffic flows, and potentially disrupt the evacuation. Therefore, the transportation modeling assumes that evacuations will occur well enough before a hurricane to preclude possible delays caused by significant weather. Moreover, the analysis assumes that provisions would be made for removal of vehicles in distress during the evacuation. The Decision Arc Method, outlined in Chapter Eight of the TDR, explains how the clearance times, used in conjunction with the dissemination times specified by officials, can provide guidance in hurricane evacuation decision-making. The time at which gale force winds arrive has been incorporated into the decision-making process of the Decision Arc Method and, therefore, does not need to be factored into the calculation of clearance time.

Evacuations for 18 combinations of storm strength, background traffic conditions, and evacuee response were simulated using the NETVAC2 computer model for both the West Bay/Rhode Island and the East Bay/Massachusetts networks. The simulated evacuations were reviewed to identify locations and duration of vehicle queuing delays (congestion), as well as to determine clearance times. The results of the simulated evacuations are presented below.

5.2 RESULTS

The NETVAC2 program presents information on traffic operations throughout the course of the simulated evacuation, including reports on vehicle arrivals and departures, roadway link speeds, and the total number of vehicles on the network for each reporting interval specified by the user. The total number of vehicles on a network can be plotted versus time to display graphically how quickly vehicles evacuate the roadway network. Figures 5-1 through 5-4 are such graphs, plotted from analysis results for the West Bay/Rhode Island and East Bay/Massachusetts networks under weak and severe hurricane evacuation scenarios, respectively. A moderate behavioral response curve was assumed for all scenarios presented in these figures. In each graph, the curves depict the numbers of vehicles remaining on a network, throughout the course of the evacuation, for evacuations starting with off-peak, mid-peak, and peak background traffic conditions.

For modeling purposes, evacuations were considered complete when the evacuating vehicles reached safe destinations. One limitation when calibrating networks to traffic patterns of a normal day is that near the completion of simulations, when most of the vehicles on the network are from evacuees rather than background traffic, vehicles adhere to turning movements of a normal day instead of seeking the most logical exit nodes. The remaining percentage on the network (2 percent) accounts for this difference. It is expected that evacuees leaving homes immediately before storm arrival will seek safe destinations of the shortest travel time. Free flow conditions are verified up to one hour before model termination to ensure the last evacuees experience light traffic free from queuing.

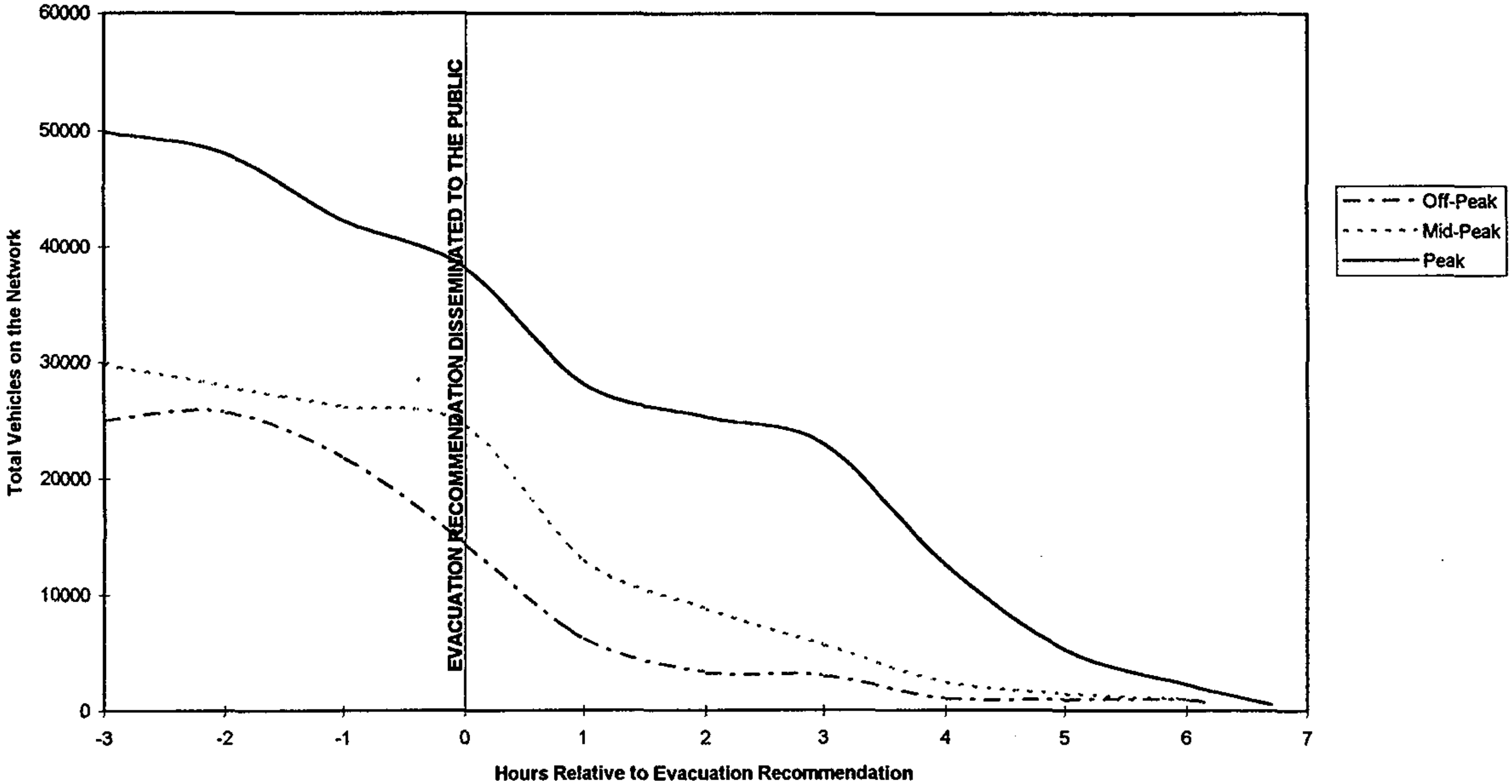
Tables 5-1 and 5-2 present the clearance times estimated for the West Bay/Rhode Island and East Bay/Massachusetts networks for weak and severe hurricane scenarios, respectively. Times are organized by intensity of hurricane, by the rate of response of the evacuating population, and by the level of background traffic at the start of the evacuation.

The clearance times were calculated assuming that each community is capable of sheltering their individual demands. The Transportation Analysis assessed how inadequate shelter capacity might influence clearance times, through sensitivity testing discussed in Section 5.3. Results showed that deficiencies in shelter capacity have a minimal affect on clearance time. This point is explained by the fact that the number of vehicles determined to travel to public shelters is very small in comparison to all vehicles on roadways. Consequently, the clearance times provided in Tables 5-1 and 5-2 are considered valid for the existing condition of deficient community shelter capacities and in the future if community sheltering capabilities improve.

Clearance times ranged from a minimum of approximately 4 hours and 15 minutes for an off-peak traffic condition under a weak hurricane scenario, to a maximum of about 9 hours and 35 minutes for a peak traffic condition under a severe hurricane scenario. The longer clearance times for the West Bay/Rhode Island network can be attributed to queuing along Route 1 from Providence to North Kingstown, as well as congestion on roads feeding into Route 1 along this same roadway section.

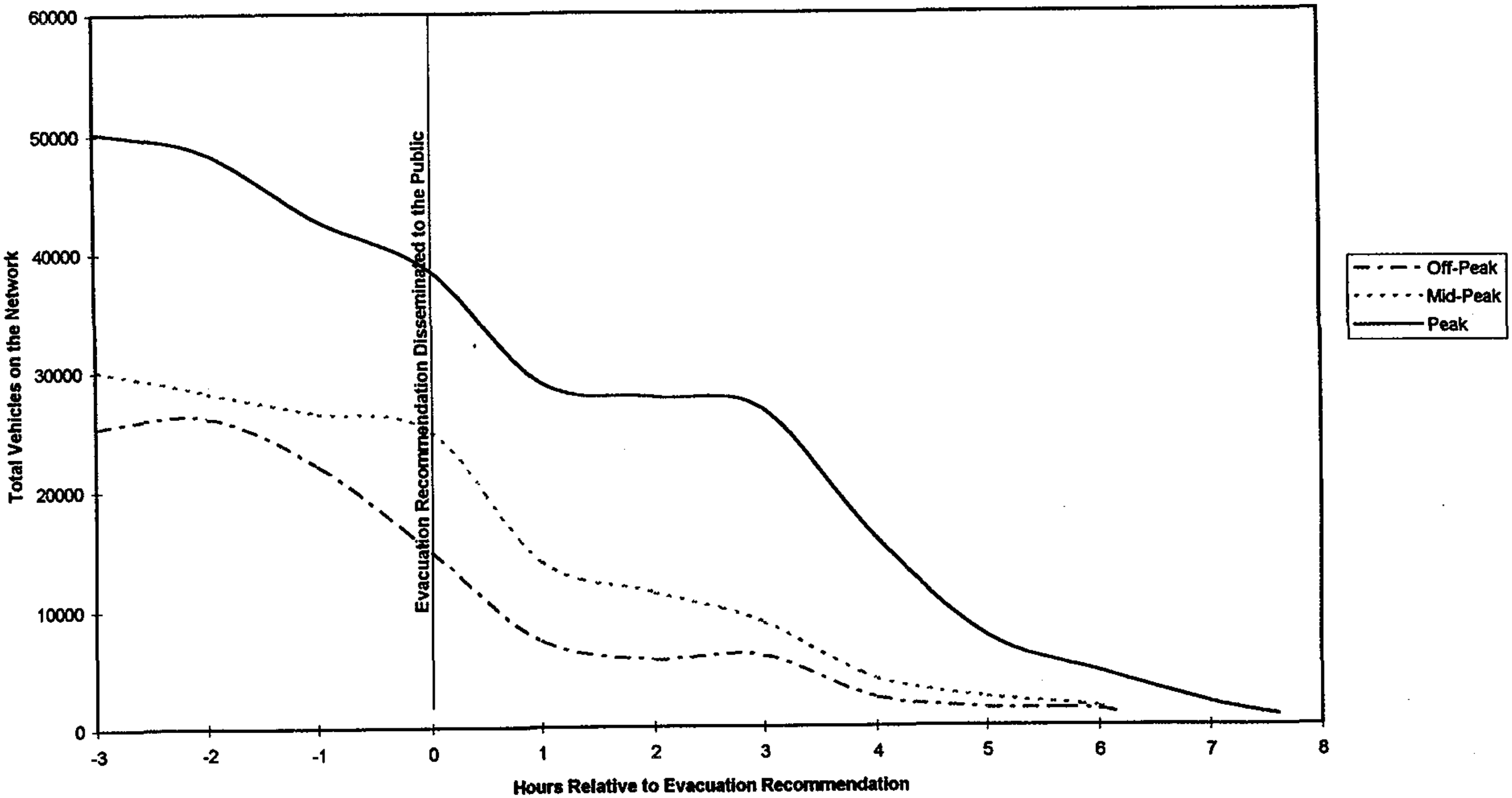
A summary of the evacuation clearance times for the West Bay/Rhode Island and East Bay/Massachusetts networks is presented in Tables 5-1 and 5-2.

FIGURE 5-1:
WEST BAY/RHODE ISLAND NETWORK PLOTTED RESULTS
FOR MODERATE BEHAVIORAL RESPONSE (WEAK HURRICANE)



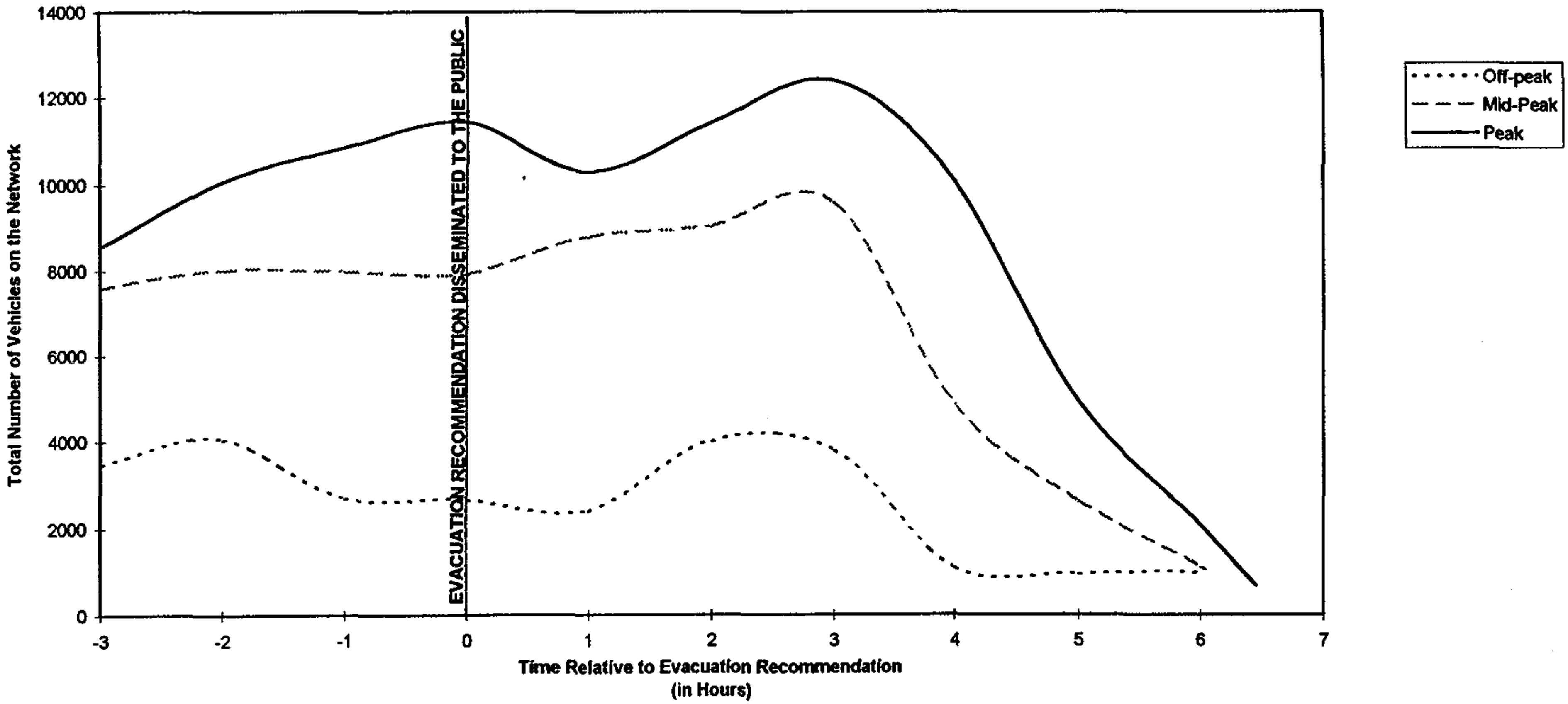
Note: **About 540 vehicles were on the network at the end of simulation** ***for all background runs.***

FIGURE 5-2:
WEST BAY/RHODE ISLAND NETWORK PLOTTED RESULTS
FOR MODERATE BEHAVIORAL RESPONSE (SEVERE HURRICANE)



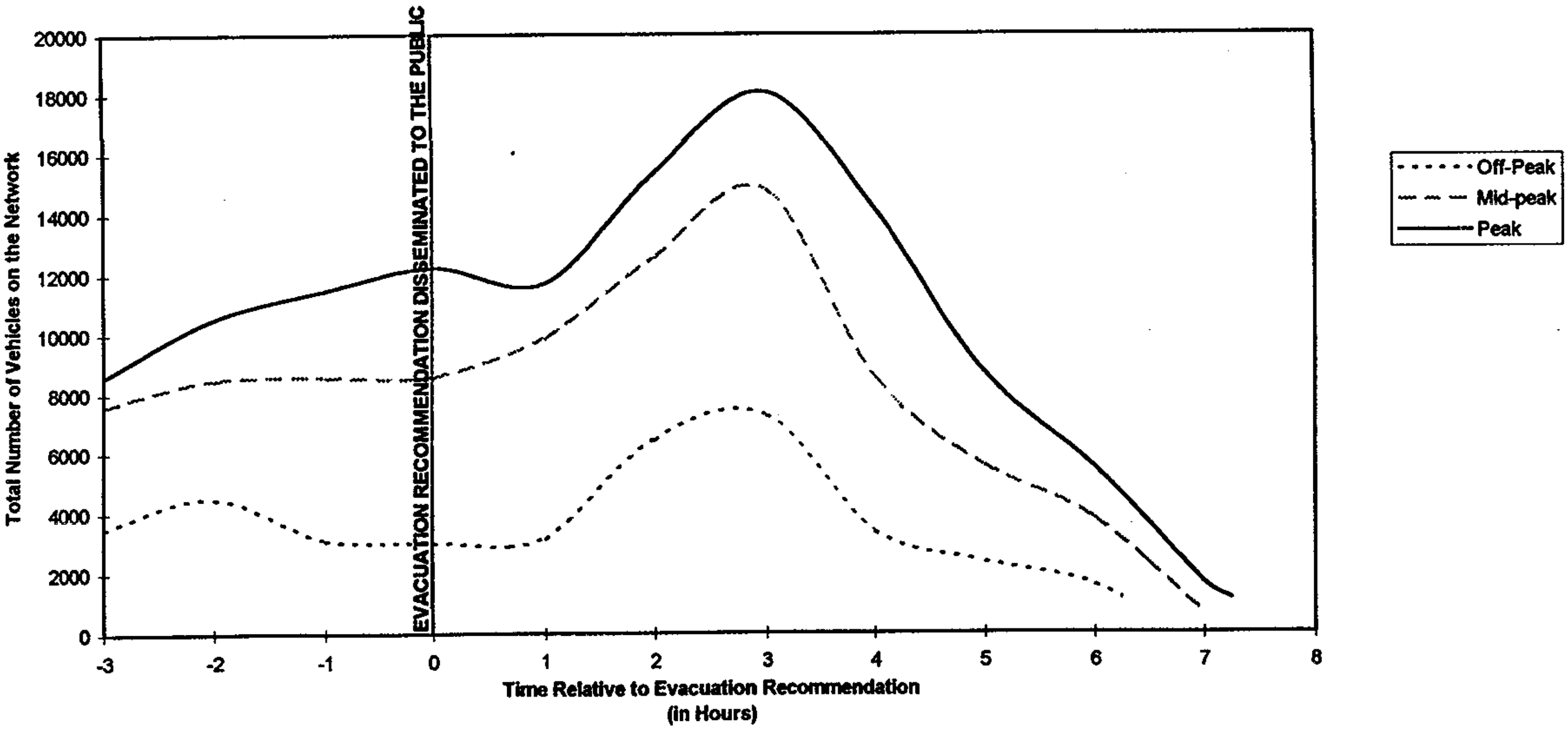
Note: **About 860 vehicles were on the network at the end of simulation for all background traffic conditions.**

FIGURE 5-3:
EAST BAY/MASSACHUSETTS NETWORK PLOTTED RESULTS
FOR MODERATE BEHAVIORAL RESPONSE (WEAK HURRICANE)



Note: About 690 vehicles were on the network at the end of simulation for all background runs.

FIGURE 5-4:
EAST BAY/MASSACHUSETTS NETWORK PLOTTED RESULTS FOR MODERATE BEHAVIORAL RESPONSE (SEVERE HURRICANE)



<u>**Note:**</u> **About 1140 vehicles were on the network at the end of simulation for all background runs.**

TABLE 5-1
SUMMARY OF CLEARANCE TIMES (Weak Hurricane Scenario)

	BACKGROUND TRAFFIC CONDITION		
	Off-peak	Mid-peak	Peak
WEST BAY/RHODE ISLAND NETWORK	Hrs:Min		
Rapid Response	4:21	4:24	4:42
Moderate Response	6:10	6:11	6:43
Slow Response	8:04	8:04	8:38
EAST BAY/MASSACHUSETTS NETWORK			
Rapid Response	4:15	4:41	5:08
Moderate Response	6:06	6:10	6:28
Slow Response	8:01	8:02	8:22

TABLE 5-2
SUMMARY OF CLEARANCE TIMES (Severe Hurricane Scenario)

	BACKGROUND TRAFFIC CONDITION		
	Off-peak	Mid-peak	Peak
WEST BAY/RHODE ISLAND NETWORK	Hrs:Min		
Rapid Response	4:35	4:42	5:33
Moderate Response	6:10	6:13	7:37
Slow Response	8:04	8:04	9:36
EAST BAY/MASSACHUSETTS NETWORK			
Rapid Response	5:07	5:33	5:44
Moderate Response	6:06	6:47	7:15
Slow Response	8:03	8:11	8:36

West Bay/Rhode Island Network

For the West Bay/Rhode Island network, clearance times ranged from a minimum of approximately 4 hours and 20 minutes to a maximum of approximately 9 hours and 35 minutes. For this network, the evacuation clearance times for off-peak and mid-peak conditions under both weak and severe hurricane scenarios are only slightly higher than the response times, indicating that the response times are the primary factor influencing the total clearance times for these conditions. For the off-peak and mid-peak conditions under both the weak and severe hurricane scenarios, simulated traffic conditions are mostly free flow, with no long-term congestion along the network. For these conditions, some intermittent queuing occurs along Route 2 in East Greenwich; Route 1 in North Kingstown and Warwick and along Route 117 and 117A in Warwick; as well as some off ramps to I-95 in Warwick and Providence. The simulations for the off peak conditions showed limited congestion along I-95 and Route 1 north of Warwick.

West Bay/Rhode Island Network clearance times for all of the peak conditions reflect more congestion and lower travel speeds in numerous areas, compared to the off-peak and mid-peak conditions. Extended queuing is predicted to occur along Route 1, from Providence to North Kingstown, along I-95 in Warwick and Providence, as well as along most ramps accessing I-95 in these communities for extended periods during the evacuation. A moderate amount of congestion is also expected to occur along Route 138, between Route 102 and the Jamestown Bridge, as well as along Routes 2 and 4 in East Greenwich. Intermittent vehicle queuing and congestion would also occur along Routes 110 and 108 in South Kingstown, and Routes 117 and 117A in Warwick. For the peak conditions, Route 1 in Warwick is the one link expected to experience the highest level of overall congestion. Route I-95 in Warwick is also expected to experience prolonged delays during portions of the evacuation, with travel speeds lowering to 25-40 miles per hour. Along Route 1, travel speeds are predicted to decrease to 15 to 25 miles per hour for much of the time after the evacuation recommendation is disseminated.

In summary, the controlling factor for clearance of the West Bay/Rhode Island network is evacuee response time for off-peak and mid-peak conditions, while increased congestion in the peak case has an impact on extending the evacuation time, over the response time, by up to approximately 1 hour and 30 minutes. The difference in clearance times between the weak hurricane and severe hurricane storm scenarios are generally less than 1 hour, indicating that the number of evacuees and available roadway capacities are not the major influence on the clearance time for the West Bay/Rhode Island network.

East Bay/Massachusetts Network

For the East Bay/Massachusetts network, clearance times range from a minimum of 4 hours and 15 minutes, to a maximum of approximately 8 hours and 35 minutes. The evacuation clearance times for off-peak and mid-peak conditions under the weak hurricane scenario are only slightly higher than the response times, indicating that the background traffic conditions are the primary factor influencing total clearance times for these conditions.

Evacuation traffic conditions for off-peak, mid-peak, and peak rapid response conditions under the weak hurricane scenario generally result in free flow conditions, except for portions of Route 6 in Swansea, and Fall River, MA, and sections of Route 114 through Portsmouth and Middleton, RI and sections of 103 through Barrington and Warren. The level of congestion however, is more prominent for the mid-peak and peak rapid response scenarios. In these locations, intermittent vehicle queuing temporarily slows travel speeds to approximately 20 to 25% of the posted travel speeds. However, for these conditions, the intermittent congestion corresponds to the loading intervals for evacuating traffic. This indicates that the intermittent congestion and reductions in travel speeds are directly related to the assumed rate at which evacuees load onto roadways.

Evacuation traffic conditions for off-peak, mid-peak, and peak rapid response conditions under the severe hurricane scenarios has greater congestion problems along Route 6 in East Providence, Swansea and Fall River; Route 103 in Barrington and Warren and sections of Route 114 through Portsmouth and Middleton, RI, particularly during the rapid response condition. This intermittent congestion also corresponds to the loading intervals for evacuating traffic.

For peak conditions under the weak hurricane scenario, and most conditions under the severe hurricane scenario, increased vehicle queuing and congestion is expected along portions of Routes 6 in Swansea, MA, and sections of Route 114 through Portsmouth and Middleton, RI. Congestion is also predicted around the major urban centers subsequent to the evacuation recommendation, including key connectors such as Routes 6, 103 and 138 in the vicinities of East Providence, RI, Fall River, MA, Somerset, MA, Swansea, MA, Bristol, RI, and Barrington, RI. The roadways which will experience the most significant vehicle queuing are Route 6, between Fall River, MA and East Providence, and Route 114, between the Mount Hope Bridge and Route 6 in East Providence, RI. Congestion is also expected along Route 103 in Barrington and Warren.

In summary, evacuation clearance times for the East Bay/Massachusetts network, for the off-peak and mid-peak, moderate and slow response conditions under the weak and severe hurricane scenarios are generally defined by the response time. Although some intermittent queuing is expected, the major factor influencing these clearance times are the times associated with behavioral response. Simulations of most of the remaining weak storm and severe storm conditions indicate that prolonged vehicle queuing and congestion will have more of an impact in defining the overall clearance time. Specifically, congestion and vehicle queuing are predicted along major arterials, such as Route 6 in New Bedford, MA, and urban roadways such as Routes 114 and 24, and 103 in the bay communities, adding up to 1 hour and 45 minutes over the response time to the rapid response scenario.

A comparison of the clearance times for the East Bay/Massachusetts network indicates that the difference in evacuating population between a weak and severe storm would generally add an hour or less to the total clearance time. This indicates that even for the mid-peak and off-peak conditions, the response time is a substantial component of the overall clearance time.

5.3 SENSITIVITY ANALYSIS

5.3.1 Overview

The purpose of the sensitivity analysis was to evaluate the impact of simulated clearance times to key parameters that may vary from the base conditions discussed earlier. The key parameters considered in this analysis are:

- Population - to evaluate the impact of increased levels of the evacuating population on simulated clearance times
- Response Time - to access the sensitivity of a reduced response time for the rapid response condition
- Evacuation Shelter Use - to see how a reduction in community shelter use would impact simulated clearance times

The intent of the sensitivity analysis was not to simulate all cases and scenarios, but rather to evaluate a range of conditions which would define appropriate bounds from which conclusions for all conditions could be drawn.

Simulations for these three sensitivity analysis conditions were evaluated first for the severe hurricane scenario. If appropriate, for cases where a significant impact was found, the weak hurricane scenario would be considered. To limit the number of simulations, only scenarios that could be considered as defining the "upper" and "lower" bounds of clearance time were considered. From the base condition results, these scenarios were determined to be rapid and slow evacuee conditions during off-peak and peak background scenarios.

5.3.2 Sensitivity to Population Increases

The effect of population increases of up to 20% on clearance times were evaluated for the conditions outlined above. The simulated results for the cases analyzed are presented in Annex C, Table AC-1.

The results indicate that, for the severe hurricane scenario, several analysis conditions are sensitive to population increases of this magnitude. The most significant increases would be associated with the peak conditions (up to an 80 minute increase for the West Bay/Rhode Island network, and up to a 60 minute increase for the East Bay/Massachusetts network).

For the off-peak slow response scenario, the 20% increase in population had little effect on the clearance time for both networks. The 20% increase in population for the off-peak rapid response condition added up to 40 minutes to the clearance time.

In summary, an increase of total evacuating population of 20% for the severe hurricane scenario would have an appreciable effect on clearance times for the peak conditions. For the West Bay/Rhode Island network the most significant increase in clearance time would occur during the rapid response condition, whereas for the East Bay/Massachusetts network the most significant increase would occur for the slow response condition. Increases for the moderate response condition would be expected to be appreciable for both networks. These differences (i.e., between the East Bay/Massachusetts, and West Bay/Rhode Island network results) are associated with differences in the ability of the networks to accommodate the added traffic under the various loading scenarios.

Overall, it can be stated that for the defining cases, a 20% increase in population will result in an increase of clearance times of up to 80 minutes (up to 1 hour with a 10% increase).

5.3.3 Sensitivity to Shorter Rapid Response Time

A shorter rapid response time was evaluated to determine how sensitive the assumptions on rapid response were to clearance times. A 2-hour decrease in rapid response time (or a total response time of 2 hours) was used for the sensitivity analysis, for the severe hurricane scenario. The results of the sensitivity analysis simulations are presented in Annex C, Table AC-2.

The results indicate that, under the severe hurricane scenario, for both the West Bay/Rhode Island and East Bay/Massachusetts network, reduced rapid response assumptions have little effect on overall clearance times. For both off-peak and peak conditions, the shorter response times produced results within approximately 50 minutes of the base condition results.

It can be concluded that for the West Bay/Rhode Island and East Bay/Massachusetts networks, a reduction in the assumed rapid response time will have little effect on the overall clearance times. When the response time is reduced to 2 hours, the roadway network and capacity constraints become more of a constraining factor influencing the total clearance time.

5.3.4 Sensitivity to a Reduction in Community Shelter Use

An analysis was also performed to determine if the assumption on the number of persons expected to use community shelters could have an appreciable effect on the clearance times. Specifically, the intent was to determine if less evacuees used the shelters than predicted, would the additional traffic on the evacuating roadways have a significant effect on the clearance times.

The analysis was conducted for the severe hurricane scenario, assuming that only half of the evacuees assumed to use shelters under the base condition would actually use the shelters. The results, presented in Annex C, Table AC-3, indicate that for this condition, the impact would be nominal for most scenarios. The greatest increase in clearance time would be approximately 35 minutes for the West Bay/Rhode Island network, and 20 minutes for the East Bay/Massachusetts network. For most other conditions, the increased times resulting from decreased shelter use was about 10 minutes or less. Accordingly, it can be concluded that for most conditions under the severe hurricane scenario, the impact of a 50% reduction in community shelter use will not have an appreciable impact on clearance times.

It can also be concluded that for the weak hurricane scenario conditions, a reduction in community shelter use would generally have a nominal impact on clearance times.

SECTION SIX

SUMMARY

The Rhode Island Transportation Analysis is one element of a more comprehensive study entitled the Rhode Island Hurricane Evacuation Study. Two major considerations in hurricane evacuation planning are: 1) how much time will it take to notify people that they must leave their homes after authorities have determined an evacuation is necessary (dissemination time), and 2) how much time will it take for people who evacuate their homes to travel roadways and reach safe destinations (clearance time). Evacuation time is defined as the combination of these two times. The overall objective of the Transportation Analysis is to develop estimates of clearance times under a variety of hurricane evacuation scenarios for coastal Rhode Island. Clearance times and the results from other technical analyses are compiled in the Technical Data Report of the Rhode Island Hurricane Evacuation Study offering State and local officials state-of-the-art information for which hurricane preparedness plans can be updated.

An evacuation simulation computer model entitled NETVAC2 was used to create a mathematical representation of the road system in Rhode Island and Bristol County, Massachusetts. The model was calibrated to the traffic patterns of a normal day (a day for which no hurricanes are forecasted) using traffic and roadway data obtained from the Rhode Island Department of Transportation and Massachusetts Highway Department. Estimates of the numbers of seasonal and permanent residents that would evacuate prior to future hurricanes were made using estimates of the total vulnerable population and application of human behavioral characteristics assumed for the study area. During evacuation simulations, evacuating vehicles were programmed to enter roadways at prescribed loading rates and compete for roadway and intersection capacities with other vehicles of different trip purposes.

Evacuation scenarios, idealizing some of the possible situations officials may be faced with while contending with the decision to issue an evacuation, were outlined. Key parameters of evacuation scenarios include the intensity or severity of the hurricane, the behavioral response of evacuees to mobilize and leave their homes, and the time of day an evacuation takes place. Because Rhode Island and Bristol County, Massachusetts support an industrial and commercial base employing many people in and near inundation areas, evacuations are complicated by the presence of commuter traffic which varies at different times of the day. A total of 18 different scenarios formulated from combinations of key parameters were analyzed using the NETVAC2 model.

For the West Bay/Rhode Island network, results showed that in situations where people left their homes over a moderate to long period of time (6 to 8 hours after being told to do so by authorities), the density and capacity of the roadway system are such that evacuating traffic clears the network in slightly greater time than response times. For the rapid response condition (where people leave their homes within 4 hours of being told to do so by authorities) during peak background traffic, vehicle queuing and congestion can add up to 1 hour and 45 minutes to the clearance time.

For off-peak and mid-peak conditions under both weak and severe hurricane scenarios, simulated traffic conditions are mostly free flow with no long-term congestion throughout the network. However, clearance times for all of the peak conditions reflect greater congestion and lower travel speeds in Providence, Warwick, East Greenwich, and North Kingstown. However, the congestion does clear soon after the loading period.

The lowest clearance time calculated was approximately 4 hours and 30 minutes for the weak hurricane scenario assuming rapid response and off-peak background traffic in the West Bay/Rhode Island and East Bay/Massachusetts networks. The highest clearance time of about 9 hours and 35 minutes was calculated for the West Bay/Rhode Island network, for the severe hurricane scenario assuming slow evacuee response during peak background traffic conditions.

All scenarios assuming slow evacuee response resulted in clearance times ranging from approximately 8 hours to 9 hours and 35 minutes in both networks, independent of the severity of the hurricane or background traffic conditions.

A sensitivity analysis has been performed to evaluate the impact of key assumptions and parameters to evacuation clearance times. This analysis has indicated the following:

- An increase of total evacuating population of 20% for the severe hurricane scenario would add up to about 80 minutes for the West Bay/Rhode Island network and up to about 60 minutes for the East Bay/Massachusetts network. For the majority of cases, the increase in clearance times associated with a 20% increase in population results in a predicted increase in clearance times of less than 10%.

- Reductions in the assumed rapid response times will have little effect on the overall clearance times, for all conditions. When the response times are reduced to 2 hours, the roadway network and capacity constraints become more of a constraining factor influencing the total clearance time.

- A reduction in the assumed use of community shelters will generally have little effect on clearance times for most conditions. The greatest increase in clearance times for both the West Bay/Rhode Island and East Bay/Massachusetts network would be about 35 minutes for the peak condition. For most other conditions, the increased times resulting from decreased shelter use would be 10 minutes or less.

As stated before, the clearance times calculated in the analysis comprise only a portion of total evacuation times. An additional time component is required for officials to effectively disseminate evacuation recommendations to the public. Dissemination time may differ by region depending on communication and warning procedures utilized by State and local officials in a particular area, and can best be estimated by the responsible state and local officials. Failure to add this component to clearance times will underestimate evacuation times which could result in insufficient time for all evacuees to safely clear the hazard area. Evacuation times can be determined by adding an appropriate amount of time for dissemination to the clearance times estimated for Rhode Island in this analysis. This topic is discussed more fully in Chapter Seven, Evacuation Times, of the Technical Data Report.

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10. US Department of Commerce, Bureau of the Census, 1990 Census of Population and Housing Summary Tape File; 1990.

ANNEX A:
RHODE ISLAND NETWORK COMPUTER INPUT FILES

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101 10211246 11 11  2 1 1 7 4 30    100 103    123
102 103 6283 11 11  2 1 1 7 4 30     75 105    107
102 123 5385 10 10  2 1 1 7 4 30     25 125
103 105 7800 11 11  2 1 1 7 4 30     80 106    801
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104 803 6000 11 11  2 1 1 7 3 50    100
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269	280	6900	22	11	2	2	1	4	2	35	75	300	276	
269	287	1500	22	11	2	2	1	4	2	35	25	288		
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275	276	1800	22	11	6	2	1	5	2	40	100	280	840	278
276	275	2100	22	11	6	2	1	5	2	40	90	325		
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336	345	9600	11	11	2	1	1	5	3	35	100	346		
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349	351	1000	11	11	2	1	1	6	4	25	50			355
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350	34913500		22	11	2	2	1	5	2	35	80	348	434	
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355	35712000		24	12	6	2	1	8	4	55	100	320		
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371	372	2700	11	11	2	1	1	1	1	25	80	374	412	
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382	397	2400	36	12	6	3	1	8	1	50	10	871		
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394	392	5250	22	11	2	2	1	5	3	40	100	397		854
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280	281	5250	22	11	6	2	1	5	3	40	4			266
281	266	9000	22	11	6	2	1	5	3	40	95	265		
253	241	6000	22	11	6	2	1	5	3	40	100	238		826
241	238	6500	22	11	6	2	1	5	4	40	90	233		
233	229	3000	22	11	6	2	1	7	4	40	100	227		
229	227	9000	22	11	6	2	1	5	4	50	100	222		
227	222	4500	22	11	6	2	1	7	4	40	100	224		
222	224	1500	22	11	6	2	1	8	4	50	50	450		
224	450	12000	22	11	6	2	1	8	4	50	100	451	180	
463	464	6000	22	11	6	2	1	8	4	50	100	465		
238	241	6500	22	11	6	2	1	5	4	40	85	253		
266	281	9000	22	11	6	2	1	5	3	40	100		280	
327	325	1000	22	11	6	2	1	7	3	40	50	275		
392	226	1500	22	11	6	2	1	7	3	40	100	393		
392	358	9000	22	11	6	2	1	7	3	40	100	386		
382	381	1500	22	11	2	2	1	4	3	35	10	380		
383	382	1500	22	11	2	2	1	4	3	35	100	397		
397	392	6000	22	11	2	2	1	5	3	40	100	394		
397	382	6000	36	12	6	3	1	8	1	50	100		415	381
398	387	1500	24	12	6	2	1	6	1	45	90	382		
387	382	1500	24	12	6	2	1	8	4	55	100	397		
226	392	1500	22	11	6	2	1	5	1	40	99	358		
026	405	6000	24	12	2	2	1	4	2	40	100	406		
027	407	6000	24	12	2	2	1	4	2	40	100	408		
028	408	6000	24	12	2	2	1	4	2	40	100	409		
029	409	6000	24	12	2	2	1	4	2	40	100	410		
415	417	12000	48	12	6	4	1	4	2	55	100	416	885	
417	416	12000	48	12	6	4	1	4	2	55	70	872		
417	885	3000	24	12	2	2	1	4	2	45	30			
430	431	3000	24	12	6	2	1	8	4	55	80	432	891	
431	432	12000	24	12	6	2	1	8	4	55	80	433		
432	433	1500	24	12	6	2	1	8	4	55	100	434		
433	434	13500	24	12	6	2	1	8	4	55	100	435	349	
434	435	10500	24	12	6	2	1	8	4	55	96	436	056	
434	349	1000	11	11	2	1	1	1	4	25	4		350	

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 435 436 3000 24 12  6 2 1 8 4 55     100 437
 436 437 1500 24 12  6 2 1 8 4 55     100 438       061
 437 061 1000 11 11  2 1 1 1 4 25      15 390
 437 438 1500 24 12  6 2 1 8 4 55      85 439
 438 43915000 24 12  6 2 1 8 4 55     100 440
 439 440 1000 24 12  6 2 1 8 4 55      90 441       075
 439 073 1000 11 11  2 1 1 1 4 25      10 396
 440 44113500 24 12  6 2 1 8 4 55      85 442       881       088
 440 075 1000 11 11  2 1 1 5 1 25      15 044
 441 881 1000 11 11  2 1 1 5 1 25      40
 441 442 1000 24 12  6 2 1 8 4 55      40 443
 441 088 1000 11 11  2 1 1 5 1 25      10
 442 44315000 24 12  6 2 1 8 4 55     100 444       882
 443 882 1000 11 11  2 1 1 5 1 25      40
 443 444 1000 24 12  6 2 1 8 3 55     100 860
 444 86042000 24 12  6 2 1 8 3 55     100
 278 887 3000 24 12  6 2 1 8 3 55      30
 330 886 3000 24 12  6 2 1 8 3 55      20
 309 888 3000 24 12  6 2 1 8 3 55      25
 257 889 3000 24 12  6 2 1 8 3 55      46
 030 386 8300 22 11  2 2 1 5 1 40     100 370
 450 18018510 11 11  2 1 1 4 4 40       5 181
 167 458 9000 10 10  2 1 1 7 4 50     100 459
 463 13910500 11 11  2 1 1 7 4 35      30 133
 141 462 4800 10 10  2 1 1 7 4 50     100                 463
 466 13110830 11 11  2 1 1 4 4 50      40 132             115
 250 245 5250 24 12  6 2 1 8 4 50     100 244
 245 244 3000 24 12  6 2 1 8 4 50     100 243
 244 243 1000 24 12  6 2 1 8 4 50     100 234
 243 234 1000 24 12  6 2 1 8 4 50     100 228             823
 129 464 6000 24 12  6 2 1 5 4 30     100                 465
 456 160 1000 11 11  4 1 1 7 4 35      35 184
 430 890 3000 24 12  6 2 1 8 2 55      20
 431 891 3000 24 12  6 2 1 8 2 55      25
 452 175 3000 24 12  6 2 1 5 2 35      25 176
 227 895 3000 24 12  6 2 1 5 2 35      75
 454 897 3000 24 12  6 2 1 5 2 40      20
 093 090 3000 36 12  6 3 1 8 4 55     100 397
99999
```

```
POPOTP1 Rhode Island Strong Storm Off-Peak Traffic, Rapid Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout1.dat'
outprint='popout1.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=270.0 int1(2)=390.0 int1(3)=400.0 int1(4)=510.0 int1(5)=630.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT2 Rhode Island Strong Storm Off-Peak Traffic, Moderate Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout2.dat'
outprint='popout2.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=120.0 int1(2)=300.0 int1(3)=360.0 int1(4)=480.0 int1(5)=660.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT3 Rhode Island Strong Storm Off-Peak Traffic, Slow Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout3.dat'
outprint='popout3.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=0.0 int1(2)=240.0 int1(3)=320.0 int1(4)=480.0 int1(5)=720.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT4 Rhode Island Strong Storm Mid-Peak Traffic, Rapid Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout4.dat'
outprint='popout4.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=840.0 int1(2)=960.0 int1(3)=1000.0 int1(4)=1080.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
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```
POPOPT5 Rhode Island Strong Storm Mid-Peak Traffic, Moderate Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout5.dat'
outprint='popout5.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=660.0 int1(2)=840.0 int1(3)=900.0 int1(4)=1020.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT6 Rhode Island Strong Storm Mid-Peak Traffic, Slow Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout6.dat'
outprint='popout6.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=480.0 int1(2)=720.0 int1(3)=800.0 int1(4)=960.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT7 Rhode Island Strong Storm Peak Traffic, Rapid Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout7.dat'
outprint='popout7.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=870.0 int1(2)=990.0 int1(3)=1030.0 int1(4)=1110.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT8 Rhode Island Strong Storm Peak Traffic, Moderate Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout8.dat'
outprint='popout8.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=690.0 int1(2)=870.0 int1(3)=930.0 int1(4)=1050.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT9 Rhode Island Strong Storm Peak Traffic, Slow Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout9.dat'
outprint='popout9.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=510.0 int1(2)=750.0 int1(3)=830.0 int1(4)=990.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT10 Rhode Island Weak Storm Off-Peak Traffic, Rapid Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout10.dat'
outprint='popout10.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=270.0 int1(2)=390.0 int1(3)=430.0 int1(4)=510.0 int1(5)=630.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT11 Rhode Island Weak Storm Off-Peak Traffic, Moderate Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout11.dat'
outprint='popout11.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=120.0 int1(2)=300.0 int1(3)=360.0 int1(4)=480.0 int1(5)=660.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT12 Rhode Island Weak Storm Off-Peak Traffic, Slow Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout12.dat'
outprint='popout12.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=0.0 int1(2)=240.0 int1(3)=320.0 int1(4)=480.0 int1(5)=720.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT13 Rhode Island Weak Storm Mid-Peak Traffic, Rapid Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout13.dat'
outprint='popout13.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=840.0 int1(2)=960.0 int1(3)=1000.0 int1(4)=1080.0 int1(4)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT14 Rhode Island Weak Storm Mid-Peak Traffic, Moderate Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout14.dat'
outprint='popout14.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=660.0 int1(2)=840.0 int1(3)=900.0 int1(4)=1020.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT15 Rhode Island Weak Storm Mid-Peak Traffic, Slow Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout15.dat'
outprint='popout15.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=480.0 int1(2)=720.0 int1(3)=800.0 int1(4)=960.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT16 Rhode Island Weak Storm Peak Traffic, Rapid Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout16.dat'
outprint='popout16.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=870.0 int1(2)=990.0 int1(3)=1030.0 int1(4)=1110.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT17 Rhode Island Weak Storm Peak Traffic, Moderate Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout17.dat'
outprint='popout17.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=690.0 int1(2)=870.0 int1(3)=930.0 int1(4)=1050.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT18 Rhode Island Weak Storm Peak Traffic, Slow Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout18.dat'
outprint='popout18.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=510.0 int1(2)=750.0 int1(3)=830.0 int1(4)=990.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

Background Traffic

NR1ANB	3	2900	1.00	194	100						
WE1NB	3	10300	1.00	155	100						
WA1NB	3	4000	1.00	331	100						
WE1SB	3	3500	1.00	129	100						
WE1SB	3	3000	1.00	467	100						
PW1SB	3	5000	1.00	092	100						
WA1SB	3	10000	1.00	030	77	370	23				
WAAPR	3	2500	1.00	274	100						
HO95NB	3	17050	1.00	077	100						
PW95SB	3	86000	1.00	086	55	359	10	383	10	381	25
BU102S	3	6300	1.00	078	100						
NK2NB	3	10000	1.00	079	100						
GL44EB	3	3500	1.00	083	100						
SC6EB	3	1000	1.00	084	100						
SC6WB	3	3600	1.00	387	100						
SC14EB	3	1200	1.00	085	100						
NA295S	3	17800	1.00	076	83	072	17				
CR295S	3	5000	1.00	057	100						
NS146S	3	6000	1.00	081	100						
BU7SB	3	1	1.00	082	100						
PR195W	3	30150	1.00	090	100						
RI138E	3	5900	1.00	091	100						
NR138W	3	8700	1.00	098	100						
NK1SB	3	1	1.00	099	100						
WEINB	3	10000	1.00	126	100						
CHRT1B	3	4000	1.00	185	100						
CHRT1B	3	2500	1.00	167	100						
SKRT1B	3	7000	1.00	209	100						
WART1B	3	4000	1.00	266	100						
WART1B	3	4000	1.00	281	100						
WART1B	3	4000	1.00	280	100						
WART1B	3	4000	1.00	276	100						
WART1B	3	8000	1.00	275	100						
WART1B	3	4000	1.00	325	100						
WART1B	3	4000	1.00	331	100						
CH2SB	3	3300	1.00	151	100						
EG4NB	3	35000	1.00	250	100						
EGQP	3	5000	1.00	235	100						
PR195W	3	20000	1.00	397	100						
SKETL	3	1000	1.00	169	100						
WA95NL	3	12000	1.00	026	100						
WA95NL	3	15000	1.00	027	100						
WA95NL	3	15000	1.00	028	100						
WA95NL	3	15000	1.00	029	100						
NK4NB	3	35000	1.00	242	50	250	50				

Severe Storm Surge Vulneralbe Population File

1	1	333	2.96	378	100		
7	1	4	2.96	379	100		
34	1	33	2.96	225	100		
35	1	166	2.96	093	100		
37	1	374	2.96	093	100		
134	1	1133	2.05	294	50	377	50
135	1	368	2.05	378	100		
136	1	409	2.05	371	100		
138	1	94	2.05	330	100		
139	1	47	2.05	330	100		
149	1	5	2.26	101	100		

Severe Storm Surge Vulneralbe Population File(con't.)

152	1	3	2.26	101	100								
153	1	54	2.26	393	100								
160	1	21	2.26	393	100								
165	1	2	2.26	393	100								
166	1	87	2.26	393	100								
167.97	1	264	2.26	101	100								
167.98	1	167	2.26	102	100								
209.01	1	1009	1.85	255	50	256	50						
210	1	1498	1.88	293	50	294	50						
211	1	204	1.88	330	100								
213	1	1888	1.88	306	50	293	50						
214.01	1	1288	1.88	215	80	306	20						
214.02	1	751	1.88	273	100								
215.01	1	2473	1.88	283	34	273	33	295	33				
215.02	1	3992	1.88	271	25	284	25	285	25	262	25		
216	1	1324	1.88	282	50	261	50						
217	1	3900	1.88	286	34	159	33	270	33				
218	1	1579	1.88	272	34	270	33	269	33				
219.01	1	230	1.88	268	100								
219.02	1	457	1.88	288	100								
219.03	1	1677	1.88	287	34	291	33	290	33				
220	1	1995	1.88	265	34	267	33	289	33				
221	1	738	1.88	322	100								
222.01	1	166	1.88	265	100								
223	1	230	1.88	279	100								
224	1	1308	1.88	216	50	217	50						
501.02	1	1052	1.83	238	50	236	50						
501.03	1	458	1.83	241	100								
501.04	1	1129	1.83	240	50	239	50						
502	1	623	1.83	240	50	236	50						
503.01	1	39	1.83	233	100								
503.02	1	1626	1.83	230	34	231	33	232	33				
504.02	1	1616	1.83	230	34	220	33	222	33				
508.01	1	1010	1.90	104	33	106	33	139	34				
508.02	1	970	1.90	103	50	105	50						
509	1	161	1.90	124	100								
510	1	3813	1.90	101	20	102	20	122	20	123	20	124	20
511.01	1	969	1.80	141	100								
511.02	1	990	1.80	143	100								
512	1	378	2.30	177	100								
513.01	1	418	2.30	160	100								
513.02	1	4170	2.30	166	34	188	33	189	33				
515.01	1	4556	1.73	190	20	191	20	193	20	201	20	203	20
515.02	1	3558	1.73	211	25	212	25	213	25	214	25		

Weak Storm Surge Vulnerable Population File

1	1	148	2.96	378	100		
7	1	2	2.96	379	100		
34	1	30	2.96	225	100		
35	1	147	2.96	093	100		
37	1	166	2.96	093	100		
134	1	952	2.05	294	50	377	50
135	1	267	2.05	378	100		
136	1	259	2.05	371	100		
138	1	83	2.05	330	100		
139	1	42	2.05	330	100		
149	1	4	2.26	101	100		
152	1	2	2.26	101	100		

Weak Storm Surge Vulnerable Population File(con't.)

153	1	48	2.26	393	100										
160	1	18	2.26	393	100										
165	1	2	2.26	393	100										
166	1	78	2.26	393	100										
167.97	1	234	2.26	101	100										
167.98	1	149	2.26	102	100										
209.01	1	720	1.85	255	50	256	50								
210	1	948	1.88	293	50	294	50								
211	1	97	1.88	330	100										
213	1	1388	1.88	306	50	293	50								
214.01	1	980	1.88	215	80	306	20								
214.02	1	406	1.88	273	100										
215.01	1	1757	1.88	283	34	273	33	295	33						
215.02	1	2469	1.88	271	25	284	25	285	25	262	25				
216	1	752	1.88	282	50	261	50								
217	1	3372	1.88	286	34	159	33	270	33						
218	1	1044	1.88	272	34	270	33	269	33						
219.01	1	182	1.88	268	100										
219.02	1	238	1.88	288	100										
219.03	1	1201	1.88	287	34	291	33	290	33						
220	1	1406	1.88	265	34	267	33	289	33						
221	1	328	1.88	281	50	322	50								
222.01	1	92	1.88	265	100										
223	1	102	1.88	279	100										
224	1	1082	1.88	216	50	217	50								
501.02	1	934	1.83	238	50	236	50								
501.03	1	262	1.83	241	100										
501.04	1	768	1.83	240	50	239	50								
502	1	552	1.83	240	50	236	50								
503.01	1	17	1.83	233	100										
503.02	1	1355	1.83	230	34	231	33	232	33						
504.02	1	1353	1.83	230	34	220	33	222	33						
508.01	1	610	1.90	104	33	106	33	139	34						
508.02	1	634	1.90	103	50	105	50								
509	1	132	1.90	124	100										
510	1	2775	1.90	101	20	102	20	122	20	123	20	124	20		
511.01	1	690	1.80	141	100										
511.02	1	638	1.80	143	100										
512	1	302	2.30	177	100										
513.01	1	371	2.30	160	100										
513.02	1	3173	2.30	166	34	188	33	189	33						
515.01	1	3246	1.73	190	20	191	20	193	20	201	20	203	20		
515.02	1	2834	1.73	211	25	212	25	213	25	214	25				

Severe Storm Mobile Home and Non-Surge Vulnerable Population File

WESTE	2	1170	1.90	107	20	131	20	113	20	132	20	127	20
CHARL	2	730	1.80	139	25	013	25	140	25	148	25		
S.KIN	2	1720	2.30	022	20	165	20	184	20	179	20	182	20
NARRA	2	550	1.73	198	20	199	20	200	20	204	20	207	20
N.KIN	2	1370	1.83	227	25	228	25	229	25	234	25		
E.GRE	2	650	1.85	244	25	246	25	247	25	403	25		
WARWI	2	3090	1.88	305	20	307	20	318	20	315	20	404	20
CRANS	2	3750	2.05	433	20	434	20	347	20	346	20	345	20
PROVI	2	8090	2.96	386	20	390	20	394	20	395	20	396	20
PAWTU	2	4440	2.26	392	50	416	50						

Weak Storm Mobile Home and Non-Surge Vulnerable Population File

WESTE	2	590	1.90	107	20	131	20	113	20	132	20	127	20
CHARL	2	490	1.80	139	25	013	25	140	25	148	25		
S.KIN	2	970	2.30	022	20	165	20	184	20	179	20	182	20
NARRA	2	230	1.73	198	20	199	20	200	20	204	20	207	20
N.KIN	2	870	1.83	227	25	228	25	229	25	234	25		
E.GRE	2	320	1.85	244	25	246	25	247	25	403	25		
WARWI	2	1360	1.88	305	20	307	20	318	20	315	20	404	20
CRANS	2	1530	2.05	433	20	434	20	347	20	346	20	345	20
PROVI	2	3290	2.96	386	20	390	20	394	20	395	20	396	20
PAWTU	2	2300	2.26	392	50	416	50						

ANNEX B:
EAST BAY/MASSACHUSETTS NETWORK COMPUTER INPUT FILES

```
001 848  600 11 11  2 1 1 5 2 25     15
070 00131150 24 12  6 2 1 8 2 55    100 100
100 001 2100 24 12  6 2 1 8 2 55     75 860             848
100 101  500 24 12  6 2 1 8 2 55     25 851             102
101 100  500 11 11  2 1 1 1 2 25     75 001
101 102  500 11 11  2 1 1 1 2 25     25 103             847
102 847 3600 11 11  2 1 1 5 2 25     20
102 10312000 11 11  2 1 1 5 2 30     25 104     821
102 101  500 11 11  2 1 1 5 2 25     55         100     851
103 10212000 11 11  2 1 1 5 2 30     55 101     847
103 821 3000 11 11  2 1 1 5 2 25     02
103 104 2700 11 11  2 1 1 5 2 30     25 105
104 103 3000 11 11  2 1 1 5 2 30     75 102             821
104 105 2700 11 11  2 1 1 5 2 30     25 133     106
105 106 5100 11 11  2 1 1 5 2 30     30 107     822
105 133 5400 11 11  2 1 1 5 2 30     30 131             030
106 105 5100 11 11  2 1 1 5 2 30     40         133     104
106 107 2100 11 11  2 1 1 5 2 30     40 108
106 822  300 11 11  2 1 1 5 2 25     15
107 106 2100 11 11  2 1 1 5 2 30     50 105     133     822
107 108 2100 11 11  2 1 1 5 2 30     50 121     113     124
108 124 2250 22 11  2 2 1 5 2 30     30 127
108 121 2100 11 11  2 1 1 5 2 30     20 122     823
108 113 1800 22 11  2 2 1 5 2 30     30 112
108 107 2100 11 11  2 1 1 5 2 30     20 106
124 127 6900 22 11  4 2 1 6 2 40     40 128
124 108 2250 22 11  2 2 1 5 2 30     40 113
131 129 2250 11 11  2 1 1 5 2 30     15 128
129 128 2250 11 11  2 1 1 5 2 30     50 127
129 131 2250 11 11  2 1 1 1 4 25     20 133             022
130 129 1000 11 11  2 1 1 1 4 25     20         128     131
022 02312000 36 12  6 3 1 8 2 55    100 031
021 022 1000 36 12  6 3 1 8 2 55     90 023
021 131 1000 11 11  2 1 1 5 2 25     10         133     129
130 132 1000 36 12  6 3 1 8 2 55     40 144
131 133 9000 11 11  2 1 1 5 2 30     05 105     030
131 022 1000 11 11  2 1 1 5 2 25     80 023
105 104 2700 11 11  2 1 1 5 2 30     40 103
106 133 5250 11 11  2 1 1 7 2 30     05 030     131
129 132 1000 11 11  2 1 1 1 2 25     30         144
109 002  750 11 11  5 2 1 5 2 30     75         852
109 11512000 11 11  2 1 1 5 2 30     25         116
110 114 8250 36 12  6 3 1 8 2 55    100 125
002 112 3000 22 11  2 2 1 5 2 30     50 113
112 002 3000 22 11  2 2 1 5 2 30     50 852
112 113 1500 22 11  2 2 1 5 2 30     50 108             114
113 112 1500 22 11  2 2 1 5 2 30     40 002
113 108 1800 22 11  2 2 1 5 2 30     40 124     121     107
114 125 6000 36 12  6 3 1 8 2 55     50 130     126
031 850 6000 36 12  6 3 1 8 2 55    100
115 116 3300 11 11  2 1 1 5 2 30     25 120             117
115 122 1800 11 11  2 1 1 5 2 30     75 121
116 115 3300 11 11  2 1 1 5 2 30     25 122
116 117 2700 11 11  2 1 1 5 2 30     75                 825
116 120 2100 11 11  2 1 1 5 2 30    100                 824
117 825 4500 11 11  2 1 1 5 2 25     02
117 116 2700 11 11  2 1 1 5 2 30     80         115
118 120 5250 11 11  2 1 1 5 2 30    100 116     824
119 117 7000 11 11  2 1 1 5 2 30    100         825     116
120 824 1000 11 11  2 1 1 5 2 30     03
```

120	116	2100	11	11	2	1	1	5	2	30	80	115	117	
121	108	1800	11	11	2	1	1	5	2	30	40	107	124	113
121	823	1000	11	11	2	1	1	5	2	25	20			
121	122	2700	11	11	2	1	1	5	2	30	40	115		
122	115	1800	11	11	2	1	1	5	2	25	30	116		
122	121	2700	11	11	2	1	1	5	2	25	30	108		823
122	123	4500	11	11	2	1	1	5	2	30	40	178		
123	126	4500	11	11	2	1	1	1	4	25	100	023		
124	023	2000	11	11	2	1	1	5	2	25	20	031		
023	031	6000	36	12	6	3	1	8	2	55	100	850		
125	13012000		36	12	6	3	1	8	2	55	80	132	129	
126	023	3900	11	11	2	1	1	1	4	25	30	031		
127	128	2100	22	11	2	2	1	5	2	30	50	141		129
127	124	5400	22	11	2	2	1	5	2	30	50	108	023	
128	127	2100	22	11	2	2	1	5	2	30	40	124		
128	14112900		22	11	4	2	1	6	4	30	40	142		
132	14421000		36	12	6	3	1	8	2	55	100	147		
133	131	9000	11	11	2	1	1	5	2	30	10	129		
133	105	5400	11	11	2	1	1	5	2	30	10	104		106
133	03030000		12	12	6	1	1	7	4	50	40	039		849
133	106	5250	12	12	6	1	1	7	4	50	40	822	105	107
128	129	2000	12	12	6	1	1	7	4	40	20	131	132	
113	114	1000	11	11	2	1	1	1	2	25	20		125	
140	145	1000	11	11	4	1	1	4	2	35	10	146	147	
140	15215900		22	11	4	2	1	5	2	30	40	151	153	
140	142	3300	11	11	2	1	1	5	2	30	40	141		
141	12812900		22	11	2	2	1	5	2	30	50	127	129	
141	142	3750	22	11	2	2	1	5	2	30	50	140		
142	141	3750	22	11	2	2	1	5	2	30	50	128		
142	140	3300	22	11	2	2	1	5	2	30	50	152		145
144	147	1000	36	12	6	3	1	8	4	55	50	150		
145	146	1000	11	11	4	1	1	4	2	35	50	020		
146	020	1000	11	11	2	1	1	1	2	25	100	021		
145	147	1000	11	11	2	1	1	1	2	25	50	150		
020	02121000		36	12	6	3	1	8	2	55	100	022	131	
147	150	1000	36	12	6	3	1	8	2	55	50	153		
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153	15610000		36	12	6	3	1	8	2	55	50	158		
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163	024	8750	22	11	4	2	1	5	2	30	55	151	025	
163	16422500		12	12	6	1	1	6	4	45	20	036	810	
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171	826	1000	11	11	2	1	1	5	4	25	20			
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173	172	3300	11	11	2	1	1	4	4	35	100	171		
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178	170	1500	11	11	2	1	1	4	4	35	40	119		171
179	058	5400	11	11	2	1	1	4	4	35	50	178		
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237	24615600		24	12	2	2	1	5	2	35	50	261		247
239	25112750		24	12	6	2	1	8	2	55	50	252		
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378 38515750 22 11  6 2 1 6 2 40     20 395
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413 39514400 22 11  6 2 1 6 2 40     40 385      399
413 416 5250 12 12  6 1 1 5 2 45      5          415
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416 008 1500 11 11  2 1 1 1 2 25     50 009
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 111 00210000 11 11  2 1 1 5 2 30    100 112        109
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 099 197 3000 11 11  4 1 1 5 4 35    100 383
 234 231 6000 11 11  2 1 1 5 4 35     50 230
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99999
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filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout1.dat'
outprint='popout1.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=270.0 int1(2)=390.0 int1(3)=400.0 int1(4)=510.0 int1(5)=630.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT2 Rhode Island Strong Storm Off-Peak Traffic, Moderate Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout2.dat'
outprint='popout2.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=120.0 int1(2)=300.0 int1(3)=360.0 int1(4)=480.0 int1(5)=660.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT3 Rhode Island Strong Storm Off-Peak Traffic, Slow Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout3.dat'
outprint='popout3.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=0.0 int1(2)=240.0 int1(3)=320.0 int1(4)=480.0 int1(5)=720.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT4 Rhode Island Strong Storm Mid-Peak Traffic, Rapid Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout4.dat'
outprint='popout4.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=840.0 int1(2)=960.0 int1(3)=1000.0 int1(4)=1080.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT5 Rhode Island Strong Storm Mid-Peak Traffic, Moderate Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout5.dat'
outprint='popout5.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=660.0 int1(2)=840.0 int1(3)=900.0 int1(4)=1020.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT6 Rhode Island Strong Storm Mid-Peak Traffic, Slow Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout6.dat'
outprint='popout6.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=480.0 int1(2)=720.0 int1(3)=800.0 int1(4)=960.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT7 Rhode Island Strong Storm Peak Traffic, Rapid Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout7.dat'
outprint='popout7.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=870.0 int1(2)=990.0 int1(3)=1030.0 int1(4)=1110.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT8 Rhode Island Strong Storm Peak Traffic, Moderate Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout8.dat'
outprint='popout8.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=690.0 int1(2)=870.0 int1(3)=930.0 int1(4)=1050.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

POPOPT9 Rhode Island Strong Storm Peak Traffic, Slow Response
&files
filename(1)='strong_w.dat'
filename(2)='mnsst_w.dat'
filename(3)='backgr_w.dat'
outfile='popout9.dat'
outprint='popout9.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=510.0 int1(2)=750.0 int1(3)=830.0 int1(4)=990.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT 10 Rhode Island Weak Storm Off-Peak Traffic, Rapid Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout10.dat'
outprint='popout10.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=270.0 int1(2)=390.0 int1(3)=430.0 int1(4)=510.0 int1(5)=630.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

```
POPOPT 11 Rhode Island Weak Storm Off-Peak Traffic, Moderate Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout11.dat'
outprint='popout11.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=120.0 int1(2)=300.0 int1(3)=360.0 int1(4)=480.0 int1(5)=660.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT12 Rhode Island Weak Storm Off-Peak Traffic, Slow Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout12.dat'
outprint='popout12.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.09 frc(3,2)=0.09 frc(3,3)=0.06 frc(3,4)=0.02
/
&timeint
int1(2)=0.0 int1(2)=240.0 int1(3)=320.0 int1(4)=480.0 int1(5)=720.0
int2(1)=0.0 int2(2)=75.0 int2(3)=150.0 int2(4)=225.0 int2(5)=300.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT13 Rhode Island Weak Storm Mid-Peak Traffic, Rapid Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout13.dat'
outprint='popout13.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=840.0 int1(2)=960.0 int1(3)=1000.0 int1(4)=1080.0 int1(4)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072

POPOPT14 Rhode Island Weak Storm Mid-Peak Traffic, Moderate Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout14.dat'
outprint='popout14.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='backgrnd'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=660.0 int1(2)=840.0 int1(3)=900.0 int1(4)=1020.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT15 Rhode Island Weak Storm Mid-Peak Traffic, Slow Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout15.dat'
outprint='popout15.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.34 frc(3,3)=0.13 frc(3,4)=0.10
/
&timeint
int1(2)=480.0 int1(2)=720.0 int1(3)=800.0 int1(4)=960.0 int1(5)=1200.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=690.0 int2(5)=840.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT16 Rhode Island Weak Storm Peak Traffic, Rapid Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout16.dat'
outprint='popout16.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=870.0 int1(2)=990.0 int1(3)=1030.0 int1(4)=1110.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT17 Rhode Island Weak Storm Peak Traffic, Moderate Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout17.dat'
outprint='popout17.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=690.0 int1(2)=870.0 int1(3)=930.0 int1(4)=1050.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

```
POPOPT18 Rhode Island Weak Storm Peak Traffic, Slow Response
&files
filename(1)='weak_w.dat'
filename(2)='mnswk_w.dat'
filename(3)='backgr_w.dat'
outfile='popout18.dat'
outprint='popout18.prt'
/
&poptype
atype(1)='vulnerable'
atype(2)='nonvul+mob'
atype(3)='background'
/
&fraction
frc(1,1)=0.15 frc(1,2)=0.10 frc(1,3)=0.50 frc(1,4)=0.25
frc(2,1)=0.15 frc(2,2)=0.10 frc(2,3)=0.50 frc(2,4)=0.25
frc(3,1)=0.05 frc(3,2)=0.35 frc(3,3)=0.31 frc(3,4)=0.12
/
&timeint
int1(2)=510.0 int1(2)=750.0 int1(3)=830.0 int1(4)=990.0 int1(5)=1230.0
int2(1)=0.0 int2(2)=240.0 int2(3)=540.0 int2(4)=720.0 int2(5)=870.0
/
194,155,331,129,467,092,030,370,274,077,086,359,383,381,078,079,083,084,387,085,076,057,081,082,0
90,091,098,099,126,185,167,209,266,281,280,276,275,325,331,151,250,235,397,169,026,027,028,029,24
2,250,072
```

Background Traffic

```
114SOUTH 3      15000 1.00 089  15 093  45 099  40
114NORTH 3      12000 1.00 090  50 098  50
24SOUTH  3      22500 1.00 074  70 092  30
24NORTH  3      11500 1.00 091  71 097  29
77SOUTH  3        300 1.00 315 100
77NORTH  3       1600 1.00 310 100
81NORTH  3       1600 1.00 086 100
81SOUTH  3       2000 1.00 081 100
88NORTH  3       3500 1.00 087 100
88SOUTH  3       1000 1.00 376 100
6EAST    3      31000 1.00 111  45 083  13 084 42
6WEST    3      17000 1.00 072  85 082  15
195EAST  3      30150 1.00 110  99 085  01
195WEST  3      16700 1.00 071 100
140SOUTH 3      13000 1.00 073 100
140NORTH 3       7000 1.00 096 100
138NORTH 3      13500 1.00 076  64 164  36
138SOUTH 3       7000 1.00 080 100
44WEST   3       8000 1.00 075 100
44EAST   3       5000 1.00 088 100
177EAST  3       1000 1.00 094 100
177WEST  3       2800 1.00 095 100
95SOUTH  3          0 1.00 070 100
```

Severe Storm Surge Vulnerable Population File

```
101.01   1         91 2.12 103 100
101.02   1        149 2.12 103 100
102      1        193 2.12 110 100
103      1        795 2.12 105  50 125  50
104      1        372 2.12 109 100
105.01   1        611 2.12 124  50 126  50
105.02   1         84 2.12 123 100
106      1       2596 2.12 118  34 119  33 120  33
107.01   1        144 2.12 117 100
107.02   1       1492 2.12 119 100
301      1       2267 1.88 170  25 171  25 172  25 173  25
302      1       2685 1.88 178  34 179  33 058  33
303      1       4127 1.88 059  16 060  16 061  17 062  17 063  17 064 17
304      1       3417 1.88 173  20 174  20 175  20 176  20 177  20
305      1       3256 2.02 190  20 191  20 192  20 193  20 200  20
306.01   1       2129 2.02 190  25 198  25 199  25 057  25
306.02   1       1371 2.02 192  50 193  50
307      1        941 2.12 112 100
308      1       1439 2.12 215 100
309.01   1        502 2.12 196 100
309.02   1       1895 2.12 282  34 283  33 382  33
401.01   1       3535 1.85 230  20 231  20 235  20 251  20 252  20
401.02   1       1213 1.85 251  20 252  20 284  20 258  20 259  20
401.03   1        158 1.85 230 100
402      1        338 2.30 260  50 272  50
403.02   1        291 2.30 267 100
403.03   1        107 2.30 261  50 271  50
404      1        680 2.30 274  25 275  25 276  25 273  25
405      1        860 2.34 281  50 282  50
406      1        156 2.34 287 100
407      1        356 2.34 276  50 292  50
408      1         81 2.34 292 100
409      1       2909 2.34 294  25 295  25 296  25 293  25
```

Severe Storm Surge Vulnerable Population File(con't.)

410	1	1562	2.34	290	50	291	50								
411	1	1795	2.34	283	34	288	33	289	33						
412	1	1809	2.34	280	34	281	33	283	33						
413	1	2131	1.69	304	20	301	20	300	20	305	20	307	20		
414	1	869	1.63	311	100										
416.01	1	337	1.80	324	100										
416.02	1	592	1.80	319	100										
417	1	1197	1.80	313	50	314	50								
6322	1	482	1.83	128	100										
6332	1	579	1.85	141	100										
6403	1	394	2.72	324	100										
6404	1	82	2.72	330	100										
6405	1	257	2.72	330	100										
6409	1	653	2.72	329	25	330	75								
6410	1	841	2.72	329	100										
6420	1	613	2.72	351	100										
6421	1	1392	2.72	366	34	367	33	350	33						
6422	1	138	2.72	366	100										
6441	1	3324	1.90	159	34	162	33	163	33						
6451	1	4807	1.90	142	20	140	20	198	20	153	20	133	20		
6461	1	1744	1.85	387	50	323	50								
6503	1	849	2.84	457	100										
6504	1	372	2.84	458	100										
6506	1	712	2.84	458	100										
6507	1	525	2.84	455	100										
6511	1	23	2.84	455	100										
6512	1	1053	2.84	454	50	455	50								
6513	1	37	2.84	453	100										
6518	1	314	2.84	452	100										
6519	1	1639	2.84	449	50	459	50								
6520	1	1618	2.84	449	50	459	50								
6521	1	100	2.84	449	100										
6524	1	1433	2.84	451	50	490	50								
6525	1	2661	2.84	427	34	490	33	491	33						
6526	1	3006	2.84	492	34	493	33	494	33						
6527	1	2176	2.84	495	34	496	33	448	33						
6528	1	1190	2.84	448	25	450	75								
6532	1	157	2.26	426	50	393	50								
6533	1	3043	2.26	421	16	422	16	423	17	410	17	424	17	446	17
6541	1	681	1.96	473	100										
6542	1	133	1.96	472	100										
6551	1	1161	2.12	465	50	470	50								
6552	1	2890	2.12	498	34	499	33	500	33						
6553	1	2627	2.12	464	25	497	25	499	25	470	25				
6554	1	4419	2.12	460	20	461	20	462	20	463	20	469	20		

Weak Storm Surge Vulnerable Population File

101.01	1	48	2.12	103	100						
101.02	1	66	2.12	103	100						
102	1	91	2.12	110	100						
103	1	353	2.12	105	50	125	50				
104	1	242	2.12	109	100						
105.01	1	470	2.12	124	50	126	50				
105.02	1	74	2.12	123	100						
106	1	2158	2.12	118	34	119	33	120	33		
107.01	1	110	2.12	117	100						
107.02	1	1128	2.12	119	100						
301	1	1270	1.88	170	25	171	25	172	25	173	25

Weak Storm Surge Vulnerable Population File(con't.)

302	1	1722	1.88	178	34	179	33	058	33						
303	1	3668	1.88	059	16	060	16	061	17	062	17	063	17	064	17
304	1	2305	1.88	173	20	174	20	175	20	176	20	177	20		
305	1	2210	2.02	190	20	191	20	192	20	193	20	200	20		
306.01	1	1569	2.02	190	25	198	25	199	25	057	25				
306.02	1	869	2.02	192	50	193	50								
307	1	429	2.12	112	100										
308	1	743	2.12	215	100										
309.01	1	400	2.12	196	100										
309.02	1	1410	2.12	282	34	283	33	382	33						
401.01	1	3088	1.85	230	20	231	20	235	20	251	20	252	20		
401.02	1	1078	1.85	251	20	252	20	284	20	258	20	259	20		
401.03	1	117	1.85	230	100										
402	1	226	2.30	260	50	272	50								
403.02	1	129	2.30	267	100										
403.03	1	48	2.30	261	50	271	50								
404	1	438	2.30	274	25	275	25	276	25	273	25				
405	1	714	2.34	281	50	282	50								
406	1	69	2.34	287	100										
407	1	233	2.34	276	50	292	50								
408	1	72	2.34	292	100										
409	1	2188	2.34	294	25	295	25	296	25	293	25				
410	1	962	2.34	290	50	291	50								
411	1	1595	2.34	283	34	288	33	289	33						
412	1	1469	2.34	280	34	281	33	283	33						
413	1	1636	1.69	304	20	301	20	300	20	305	20	307	20		
414	1	652	1.63	311	100										
416.01	1	174	1.80	324	100										
416.02	1	526	1.80	319	100										
417	1	974	1.80	313	50	314	50								
6322	1	328	1.83	128	100										
6332	1	408	1.85	141	100										
6403	1	253	2.72	324	100										
6404	1	46	2.72	330	100										
6405	1	182	2.72	330	100										
6409	1	293	2.72	329	25	330	75								
6410	1	554	2.72	329	100										
6420	1	273	2.72	351	100										
6421	1	855	2.72	366	34	367	33	350	33						
6422	1	61	2.72	366	100										
6441	1	2955	1.90	159	34	162	33	163	33						
6451	1	4273	1.90	142	20	140	20	198	20	153	20	133	20		
6461	1	1550	1.85	387	50	323	50								
6503	1	1	2.84	457	100										
6504	1	1	2.84	458	100										
6506	1	1	2.84	458	100										
6507	1	1	2.84	455	100										
6511	1	1	2.84	455	100										
6512	1	1	2.84	454	50	455	50								
6513	1	1	2.84	453	100										
6518	1	1	2.84	452	100										
6519	1	1	2.84	449	50	459	50								
6520	1	1	2.84	449	50	459	50								
6521	1	1	2.84	449	100										
6524	1	374	2.84	451	50	490	50								
6525	1	1	2.84	427	34	490	33	491	33						
6526	1	1	2.84	492	34	493	33	494	33						
6527	1	243	2.84	495	34	496	33	448	33						

Weak Storm Surge Vulnerable Population File(con't.)

6528	1	1058	2.84	448	25	450	75								
6533	1	2560	2.26	421	16	422	16	423	17	410	17	424	17	446	17
6541	1	1	1.96	473	100										
6542	1	1	1.96	472	100										
6551	1	1032	2.12	465	50	470	50								
6552	1	1	2.12	498	34	499	33	500	33						
6553	1	1	2.12	464	25	497	25	499	25	470	25				
6554	1	2815	2.12	460	20	461	20	462	20	463	20	469	20		

Severe Storm Mobile Home and Non-Surge Vulnerable Population File

ACUSHN	2	980	1.96	471	33	472	33	473	34	476			
DARTMH	2	1360	2.26	394	20	418	20	412	20	392	20	391	20
FAIRH	2	300	2.12	463	25	464	25	497	25	469	25		
FALLR	2	4490	2.72	344	20	352	20	035	20	012	20	013	20
NEWBED	2	4180	2.84	432	20	007	20	431	20	477	20	415	20
REHOB	2	410	1.85	030	25	029	25	028	25	027	25		
SEEK	2	630	1.83	133	50	128	50						
SOMER	2	750	1.90	164	33	163	33	162	34				
SWAN	2	680	1.90	142	33	025	33	156	34				
WEST	2	770	1.85	388	33	386	33	400	34				
BARR	2	110	1.88	170	20	172	20	176	20	060	20	063	20
BRIS	2	860	2.12	214	20	210	20	221	20	196	20	197	20
E.PROV	2	2320	2.12	023	20	021	20	122	20	130	20	125	20
JAMES	2	200	1.69	304	33	301	33	306	34				
L.COMP	2	340	1.63	311	50	312	50						
MIDDLE	2	1330	2.30	261	25	271	25	266	25	250	25		
NEWP	2	969	2.34	295	20	294	20	287	20	284	20	280	20
PORT	2	1670	1.85	244	20	247	20	245	20	243	20	230	20
TIVER	2	1300	1.80	321	33	319	33	320	34				
WAR	2	220	2.02	198	33	057	33	190	34				

Weak Storm Mobile Home and Non-Surge Vulnerable Population File

ACUSHN	2	830	1.96	471	33	472	33	473	34	476			
DARTMH	2	620	2.26	394	20	418	20	412	20	392	20	391	20
FAIRH	2	150	2.12	463	25	464	25	497	25	469	25		
FALLR	2	1850	2.72	344	20	352	20	035	20	012	20	013	20
NEWBED	2	1770	2.84	432	20	007	20	431	20	477	20	415	20
REHOB	2	170	1.85	030	25	029	25	028	25	027	25		
SEEK	2	250	1.83	133	50	128	50						
SOMER	2	290	1.90	164	33	163	33	162	34				
SWAN	2	220	1.90	142	33	025	33	156	34				
WEST	2	360	1.85	388	33	386	33	400	34				
BARR	2	40	1.88	170	20	172	20	176	20	060	20	063	20
BRIS	2	350	2.12	214	20	210	20	221	20	196	20	197	20
E.PROV	2	1330	2.12	023	20	021	20	122	20	130	20	125	20
JAMES	2	80	1.69	304	33	301	33	306	34				
L.COMP	2	250	1.63	311	50	312	50						
MIDDLE	2	800	2.30	261	25	271	25	266	25	250	25		
NEWP	2	390	2.34	295	20	294	20	287	20	284	20	280	20
PORT	2	1310	1.85	244	20	247	20	245	20	243	20	230	20
TIVER	2	950	1.80	321	33	319	33	320	34				
WAR	2	90	2.02	198	33	057	33	190	34				

ANNEX C: WEST BAY/RHODE ISLAND AND EAST BAY/MASSACHUSETTS NETWORK SENSITIVITY ANALYSIS SUPPORT

TABLE AC-1:

SUMMARY OF CLEARANCE TIME SENSITIVITY TO A 20% INCREASE IN EVACUATING TRAFFIC (SEVERE HURRICANE SCENARIO)

	BACKGROUND TRAFFIC CONDITION					
	Off-peak		Mid-peak		Peak	
WEST BAY/RHODE ISLAND NETWORK	B.C.*	S.A.**	B.C.*	S.A.**	B.C.*	S.A.**
Rapid Response	4:35	5:15	4:42	***	5:33	6:57
Moderate Response	6:10	***	6:13	***	7:37	***
Slow Response	8:04	8:06	8:04	***	9:38	10:00
EAST BAY/MASSACHUSETTS NETWORK						
Rapid Response	5:07	5:45	5:33	***	5:44	6:20
Moderate Response	6:06	***	6:47	***	7:15	***
Slow Response	8:03	8:08	8:11	***	8:36	9:35

* B.C. = Base Condition
** S.A. = Sensitivity Analysis
*** = Scenario was not simulated

TABLE AC-2:

SUMMARY OF CLEARANCE TIME SENSITIVITY TO A 2-HOUR DECREASE IN EVACUEE RESPONSE TIME (SEVERE HURRICANE SCENARIO)

	BACKGROUND TRAFFIC CONDITION					
	Off-peak		Mid-peak		Peak	
WEST BAY/RHODE ISLAND NETWORK	B.C.*	S.A.**	B.C.*	S.A.**	B.C.*	S.A.**
2-Hour Decrease In Rapid Response Time	4:35	4:28	4:35	***	5:33	5:33
EAST BAY/MASSACHUSETTS NETWORK						
2-Hour Decrease In Response Time	5:07	4:21	4:26	***	5:44	5:16

* B.C. = Base Condition
** S.A. = Sensitivity Analysis
*** = Scenario was not simulated

TABLE AC-3:

SUMMARY OF CLEARANCE TIME SENSITIVITY TO A 50% REDUCTION IN COMMUNITY SHELTER USE (SEVERE HURRICANE SCENARIO)

	BACKGROUND TRAFFIC CONDITION					
	Off-peak		Mid-peak			Peak
<u>WEST BAY/RHODE ISLAND NETWORK</u>	B.C.*	S.A.**	B.C.*	S.A.**	B.C.*	S.A.**
Rapid Response	4:35	4:39	4:42	***	5:33	6:09
Moderate Response	6:10	***	6:13	***	7:37	***
Slow Response	8:04	8:06	8:04	***	9:38	10:14
<u>EAST BAY/MASSACHUSETTS NETWORK</u>						
Rapid Response	5:07	5:10	5:33	***	5:44	6:04
Moderate Response	6:06	***	6:47	***	7:15	***
Slow Response	8:03	8:04	8:11	***	8:36	8:41

* B.C. = Base Condition
** S.A. = Sensitivity Analysis
*** = Scenario was not simulated

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13. ABSTRACT *(Maximum 200 words)*

This report and its companion atlases were completed as part of the Hurricane Evacuation Study program cosponsored by the Federal Emergency Management Agency and the U.S. Army Corps of Engineers. The purpose of the study is to provide the Rhode Island Emergency Management Agency and Rhode Island coastal communities with realistic data quantifying the major factors involved in hurricane evacuation decision-making. To accomplish this, the study provides information on the extent and severity of potential flooding from hurricanes, the associated vulnerable population, capacities of existing public shelters and estimated sheltering requirements, and evacuation roadway clearance times. The report also provides guidance on how this information can be used with National Hurricane Center advisories for hurricane evacuation decision-making.

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